Concept Guide on Reusable Learning Objects with Application to Soil, Water and Environmental Sciences

Sabine Grunwald[1] and K. Ramesh Reddy[2]

[1]Associate Professor and Distance Education Coordinator, Soil and Water Science Department, University of Florida, Gainesville, USA <sabgru@ufl.edu>
[2]Graduate Research Professor and Chair, Soil and Water Science Department, University of Florida, Gainesville, USA <krr@ufl.edu>

1. What are Reusable Learning Objects?

Reusable Learning Objects (RLOs) are based on a new way of thinking about learning and provide a digital educational resource that can be reused, scaled and shared from a central online repository in the support of instruction and learning. Each RLO supports a single learning objective. They vary in size, scope and level of granularity ranging from small chunks of instruction to a series of combined resources to provide a more complex learning experience.

2. Purpose and Benefits of Reusable Learning Objects

Reusable learning objects have been used in different disciplines including academia, military, government, and corporate world. They can enhance learning due to their clear organizational structure and focus on explicit learning objectives. They provide a mechanism to sustain knowledge in form of e-learning material that is available online beyond specific time-limited research projects. Basic and comprehensive knowledge as well as research and extension materials can be encapsulated in form of RLOs disseminating knowledge to a wide and diverse audience of learners. Reusable learning objects avoid the development of redundant learning materials; thus, financial, technical and human resources and time are saved. Assemblies of RLOs developed by institutions or individuals, respectively, are shared and made accessible online. These topical assemblies of RLOs can be scaled up to build large digital repositories to reach out to a global audience of learners and support instructors. The creation of RLOs is open to everybody engaging all people with content expertise (e.g. soil scientists, hydrologists, agricultural engineers, environmental scientists), ranging from academics, scientists, instructors, graduate and undergraduate students, extension agents, and learners. A major benefit is that RLOs can be used in various instructional context (Fig. 1).

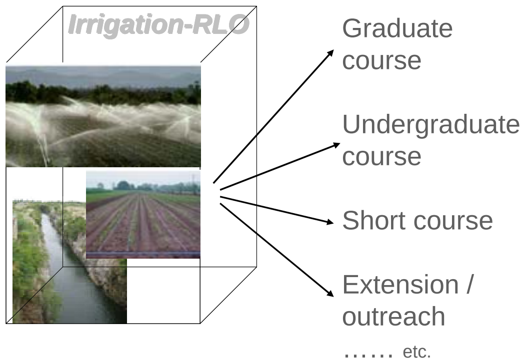


Fig. 1. A Reusable Learning Object is an independent and self-standing unit of learning content that can be used in multiple instructional context (e.g. courses or extension).

3. Characteristics of Reusable Learning Objects

The main characteristics of RLOs suggested by various authors (compare Wiley, 2002; Barritt and Alderman, 2004; McGreal, 2004; and Koohang and Harman, 2007):

(1) Digital / web-based – *24/7 accessible*

(2) Reusable – *RLOs can be used in multiple context; for multiple purpose; at multiple times (e.g. RLOs can be used to teach an undergraduate or graduate course, short course, certificate course, or extension/outreach)*

(3) Self-contained – *each RLO focuses on a specific topic / learning objective*

(4) Small in size – *to focus learner's attention (2-15 minutes)*

(5) Standardized – *RLOs follow the same organizational structure; free of look- and feel of formatting to be reused in multiple delivery media*

(6) Searchable – *RLOs are tagged with metadata (information that describes the RLO)*

(7) Flexible – *RLOs are easy to update; provide access to quality teaching and learning resources for a wide range of learners*

(8) Interoperable – *RLOs operate across different platforms and communicate with other tools to build larger modules, courses or curricula*

(9) Suited for new types of learners – *net-generation learner; learner-centered*

(10) Cost-effective – *avoid duplication of learning materials; provide intellectual capital.*

To meet all RLO characteristics outlined above is not a simple task. This paper provides background and a conceptual guide on implementing RLOs with application to soil, water and environmental sciences.

4. Types of Learning Objects (LO)

The term LO means many things to many people. They have been used in different disciplines including academia, military, government and corporate world. The broadest definition was provided by the Learning Technology Standards Committee (LTSC) (2002): "A LO is any entity (digital or non-digital) that can be reused or referenced including multimedia content, instructional content, software, persons, organizations, or events for technology supported learning. This definition leaves space for an entire curriculum to be viewed as a LO, which diminishes the possibility of LO reuse. Such an extremely broad and confusing definition is less practical because in essence everything becomes a LO (e.g. handouts, courses, and web sites).

McGreal (2004) presented various different definitions of LO of which the simplest description refer to *data, content* or *information objects*. While no two people may ever reach a common definition of instruction, most would agree that instruction is more than information. Merrill et al. (1991) argued that learning requires context, because without context information is meaningless. According to Merrill et al. (1991) we need to develop understanding of a subject of discipline before we can learn facts, i.e., learners need some sort of prior understanding to anchor the facts before they are meaningful. These understandings, and the facts students' link to them, are called *knowledge objects*. This perspective is rooted in a constructivist view of learning emphasizing that social understanding and context are inseparable. Constructivists believe that humans come to formal education (and training) with a range of prior knowledge, skills, beliefs and concepts that significantly influence what they notice about the environment and how they organize and interpret it. This in turn, affects their abilities to remember, reason, solve problems and acquire new knowledge. Learning objects that target different learner audiences (e.g. graduate level, extension, and continued education), learners with different background and expertise (e.g. farmers, students, and scientists), and learners with different cultural background need to take this into consideration when designing them.

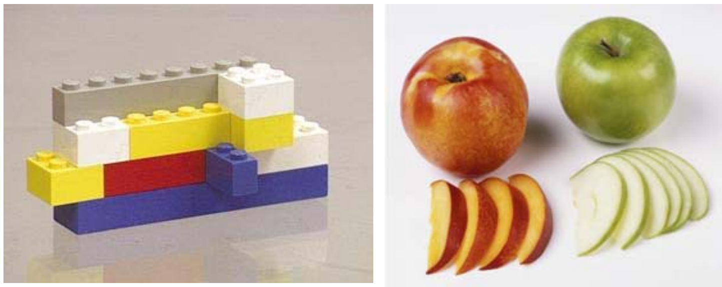


Fig. 2. Lego blocks and slices of an apple (source photographs: Google.com Images) representing Reusable Learning Objects.

Widespread credit to introduce the term *Reusable Learning Object* is given to Wayne Hodgins (in Wiley, 2002) that was inspired by one of his children playing with Lego building blocks (Fig. 2), while mulling over some problems regarding learning strategies. Hodgins suggested that building blocks for learning, plug-and-play interoperable pieces of learning, are needed. Reusable learning objects are perceived as the smallest, standalone unit of learning that can be transposed on a specific topic. This is similar to slicing up an apple into smaller pieces (or RLOs) (Fig. 2) where many pieces (multiple RLOs) make-up the whole apple (represent broader knowledge). Reusable learning objects can be lined-up in sequential mode using learning management systems such as WebCT/Blackboard or Moodle. Learning management systems allow instructors to customize learning content (e.g. provided in form of RLOs) and then critically discuss content and context in online or on-campus classrooms. Online forums can likewise provide an environment for in-depth discussions on knowledge encapsulated in form of RLOs.

Other definitions that emphasize the reusability aspect of learning materials were provided by Wiley (2007) and Rehak and Mason (2003). According to Polsani (2003) a RLO is an independent and self-standing unit of learning content that is predisposed to reuse in multiple instructional context. Given this definition, RLOs provide a digital educational resource that can be reused, scaled and shared from a central online repository. Gibbons and Nelson (2002) define *instructional objects* that address specific instructional design objectives, whereas Zimmerman and Bomme (2002) describe *intelligent objects* that react to the environment. The latter objects are the most complex ones, because they are adaptable to learner's knowledge and background (Fig. 3).

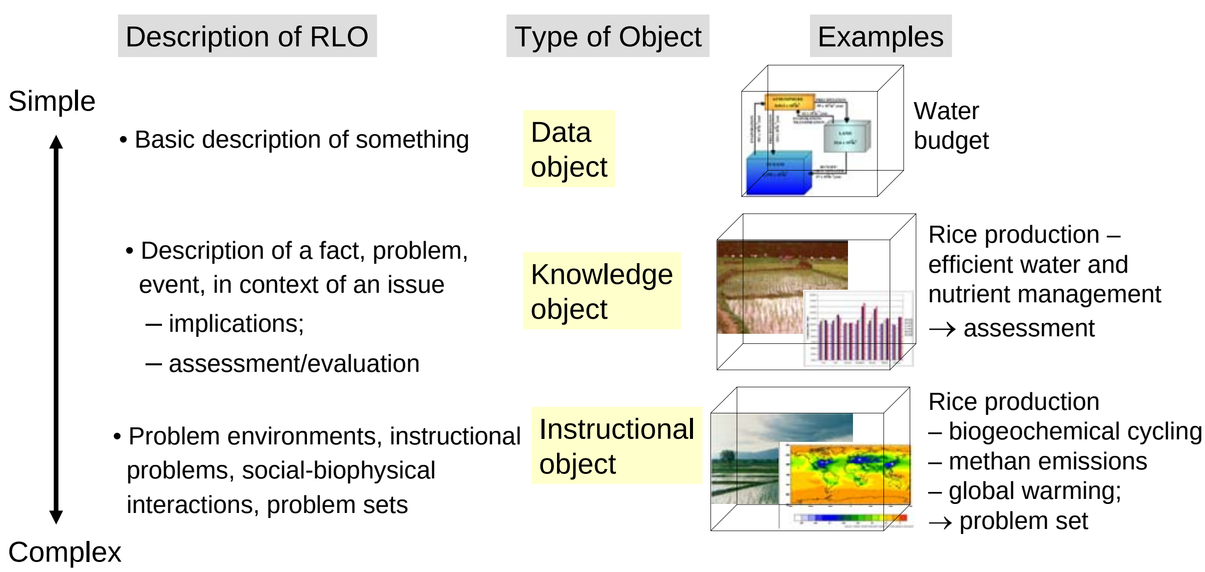


Fig. 3. Description and examples for simple and complex Reusable Learning Objects.

Reusable Learning Objects can be implemented at different levels ranging from simple (e.g. data objects) to complex learning materials (e.g. instructional objects) (Fig. 3). Data objects have the purpose to transmit basic knowledge on a topic (e.g. textbook knowledge; extension material). In contrast, complex RLOs have the ability to stimulate critical thinking and problem solving skills and are able to address current and future problems. All different types of RLOs are equally important and may serve different learning purposes.

5. Knowledge Representation in Form of Reusable Learning Objects

To organize knowledge in a graduate/undergraduate course or extension training session is important and often the material is disaggregated into modules, sections or chapters. The use of explicit knowledge representation through ontologies has been suggested by Aroyo and Dicheval (2004), Pahl et al. (2007), and others to organize knowledge. Ontologies are knowledge representation frameworks that allow expressing knowledge in an explicit and expressive way with well defined semantics (semantics refers to aspects of meaning expressed in language or other systems of signs). They describe and structure an area of knowledge by defining the common concepts of that domain (e.g. water management, ecosystem services) and the concepts' properties and relationships (Daconta et al., 2003). Ontologies are similar to mind-maps and have much value to structure learning content.

An example how knowledge can be represented and organized in form of RLOs is presented in Fig. 4. The topic "Water" can be categorized into "Water Resources", "Water Quality", "Ground Water", "Human Dimension" and more. Generic knowledge on "Water Resources" may be represented in form of RLOs including "Water Cycle", "Water Budget", "Water Quality", etc. providing a global perspective. Other RLOs describe knowledge on "Water Quality" including "Nutrients" and subsets of "Nitrogen" and "Phosphorus (P)" and further subsets of "P in aquatic systems", "P loads", and "Spatial distribution of P across a watershed". These RLOs are explicitly focused on a narrow topic but fit under the wide umbrella of "Water Quality" and "Water Resources". All RLOs are separate units of learning in the sense that they focus on a specific topic and have specific learning objectives (i.e. they are standalone, reusable learning units). At the same time they have contextual linkages to other RLOs and may be sequenced to cover more knowledge and build a whole course. "Ground water" may be disaggregated into smaller subsets of "Physics" and "Management" with further specific subsets.

Some knowledge is generic because it builds on physical, chemical, biological and mathematical understanding on specific topics. For example, the process of surface runoff can be described in form of conceptual and physical models that are well accepted by scientists around the globe and may be represented in a *data RLO* that mechanistically explains the hydrologic process of surface runoff. Although the process of surface runoff operates on the same physical principles there are different environmental factors (such as slope, rainfall amount, and land use) that control it, which may differ geographically. Regionalized *knowledge RLOs* that account for the occurrence and spatial distribution of these factors that control surface runoff could transmit this kind of knowledge. Other RLOs that focus on contextual linkages can be build to explain more complex knowledge. For example, an *instructional RLO* focused to explain cause-effect relationships between surface runoff - transport of pollutants - and surface water quality could be developed to explain complex relationships among different processes, landscape properties and their effects. Similarly, complex *instructional RLOs* could focus on linking human dimension and water, e.g. "Interactions between water quality and human health" or more specifically on "Effects of E. coli on human health". Ontologies can help to structure knowledge encapsulated in form of meta-tagged RLOs (e.g. via keywords attached to each RLO). Users (e.g. instructors and students) interested in a specific topic can then identify meta-tagged RLOs via search engines.

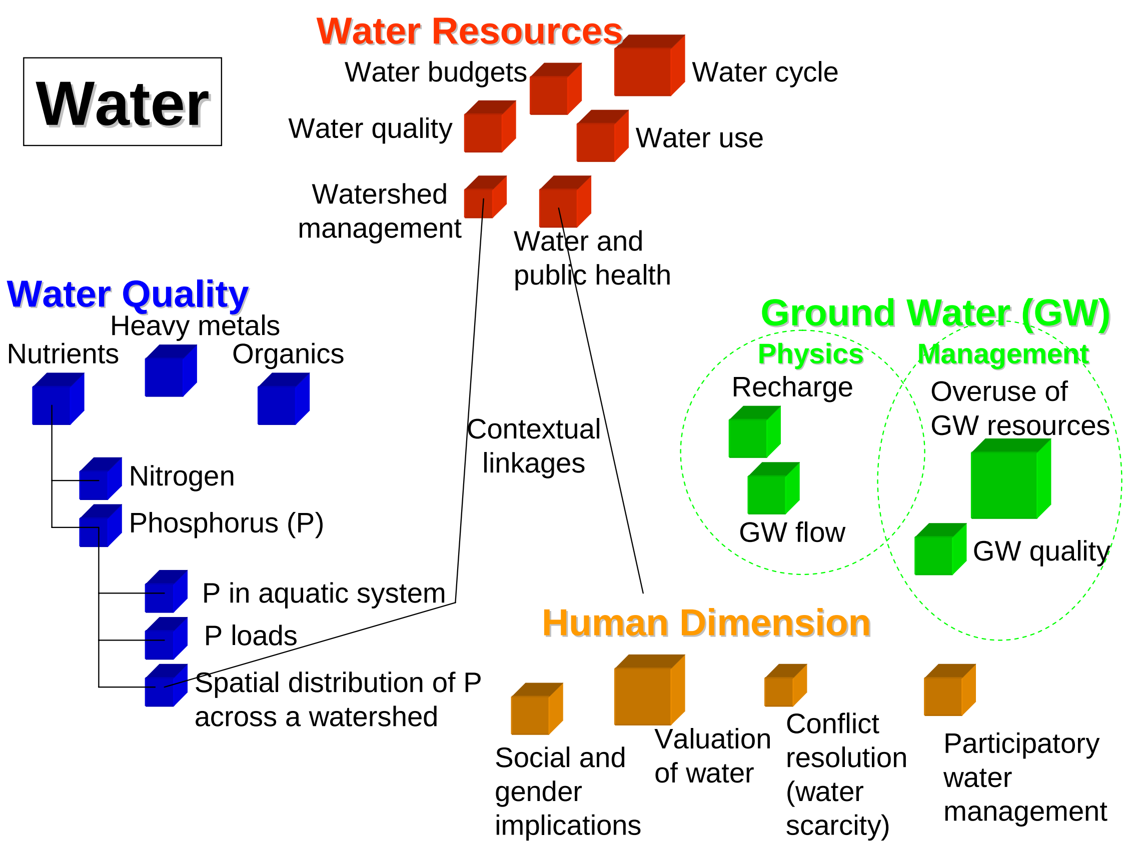
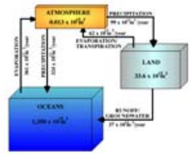
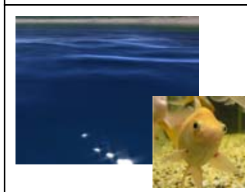
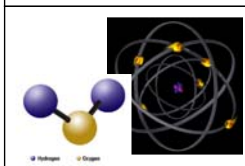


Fig. 4. Knowledge representation on "Water" in form of Reusable Learning Objects (RLO) (shown as blocks). The size of blocks represents the size (length) of a specific RLO. Black lines provide examples of contextual linkages among RLOs.

Dimensions of Water	Potential RLOs
	Global water cycle
	Water quality Most dirty rivers on earth (WWF, 2007) 1. Jangtze; 2. Mekong; 3. Saluen; 4. Ganges
	Watershed; water budget
	Water usage; water distribu-tion
	Human dimension: Water and people
	Water and ecology
	Biogeochemical processes in aquatic ecosystems

Knowledge can be transposed as learning material in many different forms adjusting to diverse learning styles. For example, the dimensions of water can be viewed from multiple perspectives that are equally important including: (i) process-understanding at different spatial and temporal scales (e.g. biogeochemical processes in aquatic systems at micro-/field scale; hydrologic flux within larger watersheds; water distribution/budgets at global scale); (ii) interaction with ecosystem components (water ecology); (iii) human dimension (socio-economic and cultural issues related to water use, safety and health); (iv) water resource and quality problems (e.g. water shortage and pollution); and more (Fig. 5). Reusable learning objects are not limited to specific topical areas. The learning objective to develop a RLO can be broad (e.g. to explain the global water cycle) or specific (e.g. to explain denitrification in an anaerobic environment). Advanced research knowledge as well as simple facts (e.g. for outreach and continued education) can be implemented in form of RLOs. Important criteria to consider when implementing RLOs is to adapt the knowledge into a specific learning context, explicitly define learning objectives, level of complexity of knowledge encoded in a RLO, and target audience. This process of contextualizing RLOs is critical to allow users (e.g. instructors or students) to identify the RLO of interest.

Fig. 5. Example how knowledge of water can be encapsulated in form of Reusable Learning Objects (source photos/images: Goolge.com Images).

6. Implementation of Reusable Learning Objects

Reusable learning objects can be implemented in a variety of digital modes including text entries, images, illustrations, photographs, Power Point slides, figures, maps, graphs, simulations, models, audio, video, Flash animations, interactive tools and their combinations. It has been shown that knowledge is absorbed best when using more that one human sense including passive, student-centered learning (e.g. via readings, video clips, or audio recordings) and active, student-computer based learning (e.g. interactive Flash animations, interactive maps, web tools, or simulations) (Koussoulakou and Kraak, 1992; Barraclough and Guymer, 1998; Ramasundaram et al., 2005; Grunwald et al., 2007). It is a combination of technologies and media that can provide a rich learning environment that engages learners. Reusable learning objects that mix digital technologies, accommodating various learning styles, have the potential to improve learning outcomes. For example, a RLO implemented only using reading material may not engage learners, while a flashy video combined with audio and graphics may stimulate more interest in learners.

7. Granularity and Scale of Reusable Learning Objects

Reusable learning objects vary in size and scope. Some RLOs are short (2-4 minutes of learning), while others require more time (max. about 15 minutes of learning). If RLOs are too long (e.g. 1 hour) they reduce the potential to be reusable and do not accommodate the attention span of most learners. On the other hand, if a RLO is too short (e.g. a RLO consisting of only one photograph or one sentence of text) it has limited use to stimulate learning. What is the ideal length (granularity; size) of a RLO?

To address the granularity issue of LOs Wiley (2002) used the atom as a metaphor, which is something that can be understood across cultural and geographic boundaries. While pushing a metaphor is risky business, because all metaphors break down at some point, metaphors can be useful as properly contextualized educational exercises. This might jump start our understanding of RLOs and the way they are put together into instructionally meaningful units. An atom is a small thing that can be combined and recombined with other atoms to form larger things (Fig. 6). Not every atom (RLO) is combinable with every other atom (RLO). Atoms (RLOs) can only be assembled in certain structures prescribed by their own internal structure. It is commonly accepted that atoms (RLOs) are not the smallest bits in the universe. Atoms are in fact, combinations of smaller bits (baryons and mesons), which are combinations of even smaller bits (quarks, anti-quarks, and gluons). Similarly, RLOs consists of components of learning material which are implemented in form of Power Point slides, video clips, text or other. It is the particular manner in which the top-level bits (neutrons, protons and electrons) are combined in an individual atom (RLO) that determines which other atoms (RLOs) a particular atom (RLO) can bond with. In other words, it is the structure of the combination that determines what other structures the combination is compatible with. Applying this to RLOs - apparently a RLO of a finer grain size (smaller bits) may be combined into structures that promote one RLO with another one, while the same structure prevents the first object's combination with a third. Atomic bonding is a fairly precise science, and although the theories that explain it are well understood (albeit probabilistically) at the macro-level of neutrons, electrons, and protons, atomic bonding is less well understood at the smaller bits level. While the smaller bits are still an area of research, this does not prevent fruitful work from occurring at the macro-level. Similarly, instructional design theories function at a higher level, while less is understood about the exact details of the smaller instructional bits. All RLOs have certain qualities to encode different type of knowledge. It is the difference in the degree at which (or manner in which) they exhibit these qualities that makes one type of RLO different from another.

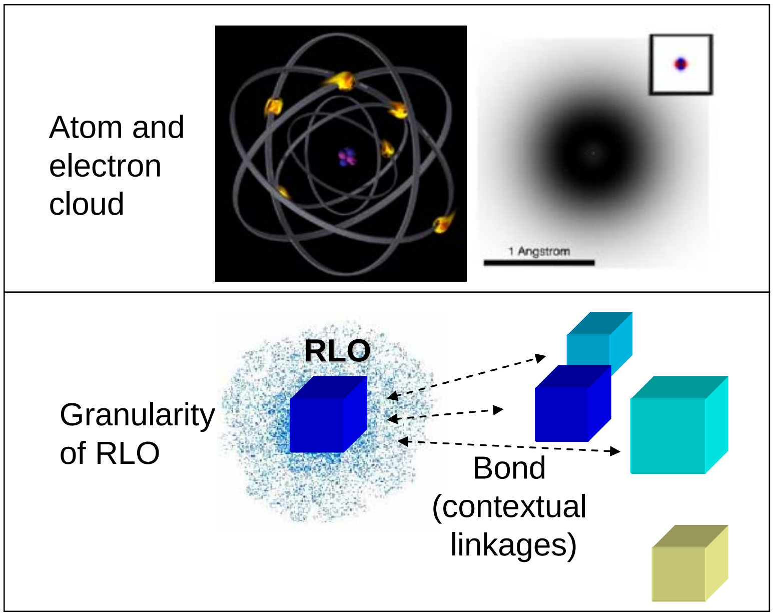


Fig. 6. Atom and electron cloud (source: Google.com Images) with nucleus in the center surrounded by a cloud where electrons are likely to be found. The atom was suggested by Wiley (2002) as a metaphor to resemble the organizational model of Reusable Learning Objects (RLOs), which differ in size and may bond (show contextual linkages) to some other RLOs but not all of them.

Topical RLOs should be thought of as the smallest possible educational unit (2-15 minutes of learning) to accommodate the short attention span of learners. Several RLOs can be brought together in order to create an instructional situation (Fig. 7). How many RLOs, how they are related, and for what purposes they are combined will be determined by the instructor's objectives, pedagogical methodology, and instructional design theories. A sequence of RLOs may form a self-paced student-only course, teacher-led course or community-based online setting that provides a learning experience.

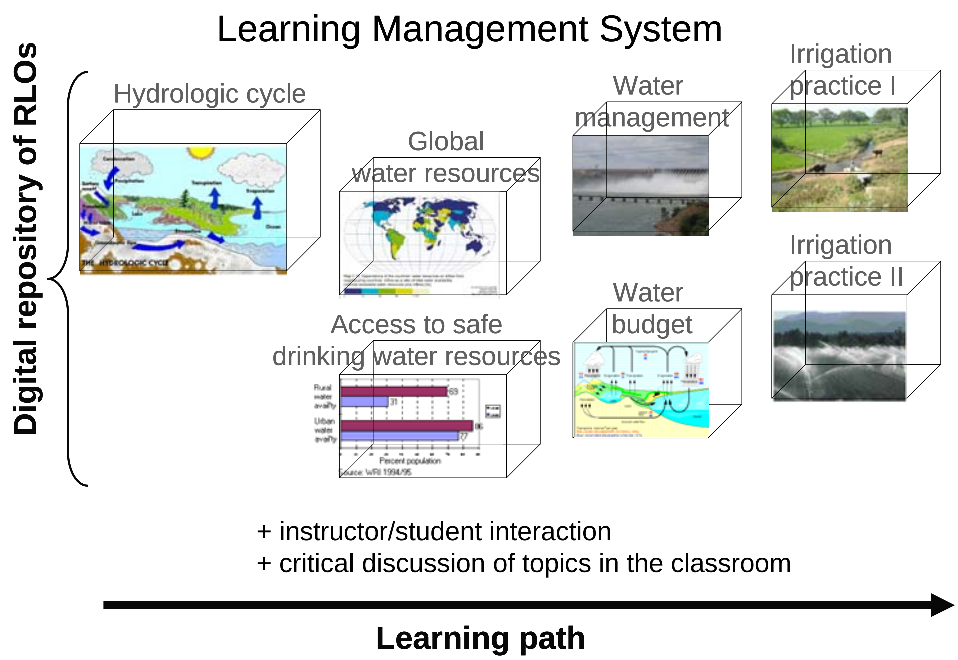


Fig. 7. Reusable Learning Objects sequenced to form a course using the platform of a Learning Management System.

8. Pedagogical Aspects

Although sound pedagogical principles should inform the creation of a RLO, it does not necessarily mean that RLOs need to comply with any specific teaching methodology or instructional theory. Ideally, RLOs should be implemented to accommodate different learning styles rooted in pedagogical concepts from the lowest level of simple knowledge to the higher cognitive skills addressing the complexity of learning. Bloom (1984) identified different levels of learning: (i) Knowledge - ability to memorize and recall a fact; (ii) Comprehension - ability to grasp meaning of a learning unit; (iii) Application - ability to use the information/skill learned in a new and concrete situation; (iv) Analysis - ability to identify the parts of a complex problem; (v) Synthesis - ability to aggregate parts into new entities; and (vi) evaluation - ability to judge the learning content. These different levels of learning can be applied to build RLOs adopting a specific learning model. For example, Bloom's taxonomy has been adopted for rapid prototyping of LOs for agricultural and biological engineering education (Sepúlveda et al., 2006). Learning object pioneers such as NETg standardized LOs into the following format: (i) Learning objective; (ii) A unit of instruction that teaches the objective; and (iii) A unit of assessment that measures the objective. Barritt and Alderman (2004) describe CISCOs successful RLO strategy that at its core contains (i) content, (ii) practice, and (iii) assessment components to meet a specific learning objective.

Traditionally, instruction has been top-down with the instructor delivering knowledge to students in the classroom. Recently, communication scientists have observed a different phenomenon of bottom-up communication/learning where students/learners participate in populating and developing learning materials. This concept blends with the ongoing migration of the Internet to the second generation Internet (Web 2.0) where online material is generated by user communities (e.g. Wikipedia). Digital repositories of RLOs can be populated by everybody with motivation, content expertise and willingness to share learning materials. The tremendous content expertise of online and local communities is equally important to build larger assemblies of RLO focused on specific topical areas.

9. Digital Reusable Learning Object Repositories

Digital repositories of RLOs support education efforts that benefit multiple instructors, undergraduate/graduate students, support course and curricula development, and extension/outreach activities. The *EcoLearnIT* (http://EcoLearnIT.ifas.ufl.edu) digital repository manages and hosts various RLOs focused on soil, water and environmental sciences and provides authoring tools to develop RLOs. *EcoLearnIT* is a peer-reviewed system that facilitates learning at all levels ranging from simple to complex knowledge encapsulated into different types of RLOs targeting various learning audiences. Pedagogical principles are used to build RLOs in *EcoLearnIT* that is an open-access digital repository.

Other repositories that provide access to e-learning materials are MERLOT (Multimedia Educational Resource for Learning and Online Teaching; http://www.merlot.org), DLESE (Digital Library for Earth System Education; http://www.dlese.org), SLOOP (Sharing Learning Objects in an Open Perspective), Orange Grove (http://www.fldlc.org/harvestroad.htm), and others.

10. Standards

One major impediment to develop LOs has been the lack in standards because these are largely work in progress. Among the more important ones are the Shareable Content Object Reference Model (SCORM) by the Advanced Distributed Learning (ADL), the IMS Global Learning Consortium, and the Institute of Electrical and Electronics Engineers (IEEE).

References

Aroyo L. and D. Dicheva. 2004. The new challenged for e-learning: the educational semantic web. Educational Technology and Society, 7(4): 59-69.

Barraclough A. and I. Guymer. 1998. Virtual reality – a role in environmental engineering education? Water Science and Technology 38(11): 303-310.

Barritt C. and F. Lee Alderman. 2004. Creating a Reusable Learning Objects Strategy. John Wiley & Sons Inc., San Francisco, CA.

Bloom B.S. 1984. Taxonomy of Educational Objectives. Publ. Allyn and Bacon, Boston, MA.

Daconta M.C., L.J. Obrst and K.T. Smith. 2003. The semantic web. Wiley Publishing Inc., Indianapolis, IN.

Gibbons A.S. and J. Nelson. 2002. The Nature and origin of instructional objects. *In* Wiley D.A. (ed.) The Instructional Use of Learning Objects. AIT/AECT, Bloomington, IN.

Grunwald S., V. Ramasundaram, G.L. Bruland and D.K. Jesseman. 2007. Expanding distance education in the spatial sciences through virtual learning entities and a virtual GIS computer laboratory. J. of Distance Education Technologies 5(1): 48-63.

Learning Technology Standards Committee (LTSC). 2002. IEEE Standard for Learning Object Metadata. IEEE Standard 1484.12.1, Institute of Electrical and Electronics Engineers, New York.

Koohang A. and K. Harman (eds.) 2007. Learning Objects: Theory, Praxis, Issues and Trends. Informing Science Press, Santa Rosa, CA.

Koussoulakou A. and M.J. Kraak. 1992. Spatio-temporal maps and cartographic communication. Cartographic J. 29: 101-108.

McGreal R. 2004. Online Education Using Learning Objects. Rutledge Publ., New York, NY.

Merrill M.D., Li Z. and Jones M. 1991. Instructional transaction theory: An introduction. Educational Technology 31(6): 7-12.

Pahl C., E. Holohan, D. McCullen and M. Melia. 2007. An ontology-based learning object-centered architecture for learning content management systems. pp. 549-583. *In* Koohang A. and K. Harman (eds.) Learning Objects: Theory, Praxis, Issues and Trends. Informing Science Press, Santa Rosa, CA.

Polsani P.R. 2003. Use and abuse of Reusable Learning Objects. J. of Digital Information 3(4) No. 164. Available at: http://jodi.ecs.soton.ac.uk/Articles/v03/i04/Polsani/

Ramasundaram V., S. Grunwald, A. Mangeot, N.B. Comerford and C.M. Bliss. 2005. Development of an environmental virtual field laboratory. J. Computers & Education 45: 21-34.

Rehak D.R. and R. Mason. 2003. Keeping the learning in learning objects. pp.22-30. *In* Littlejohn A. (ed.) Reusing online resources: a sustainable approach to e-Learning. Kogan Page, London.

Sepúlveda E.S., F.S. Zazueta, R. Bucklin, and E. Holzapfel Hoces. 2006. Rapid prototyping of learning objects for agricultural and biological engineering education. Applied Engineering in Agriculture 22(3):461-475.

Wiley D.A (ed.). 2002. The instructional use of learning objects. Agency for Instructional Technology and Association for Educational Communications & Technology, Bloomington, IN.

Wiley D.A. (ed). 2007. Connecting learning objects to instructional design theory: A definition, a metaphor, and a taxonomy; http://reusability.org/read/ (verified Dec. 2007).

Zimmerman T.H. and B. Bomme, 2002. Toward intelligent object-oriented scientific applications. Engineering Computational Technology: 271- 311.