An Inclusive Approach to Learning object architectures: Portfolios and RDF

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Learning Objectives

The purpose of this chapter is to explain why an inclusive approach to learning objects architectures is beneficial and describe how e-portfolios using RDF and OWL support this approach. By the end of the chapter the reader will

- Understand the benefits of an inclusive approach to learning objects and learning object architectures.
- Be able to identify the different priorities of different constituencies with an interest in learning object systems.
- Understand the systemic structural problems of using markup-based approaches involving html and XML at page-description level as the basis for learning object systems.
- Understand how RDF resolves many of the problems of learning object systems found in markup-based html and XML systems. Understand the benefits of a top-level framework for interoperability based on RDF.
- Derive insights from e-portfolios into best practice in learning object systems. Understand how e-e-portfolios provide a complex picture of learning
- Understand the benefits of linking learning object systems to other resource management systems.
- Understand factors affecting choice of technology and the distribution of power and control of learning object economies.

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Executive Summary

This chapter outlines an *inclusive* perspective on learning objects that includes ***all*** aspects of an educational situation that contribute to, are important to, and support learning activity and makes the case for such an approach. This *inclusive* perspective on learning objects points to advantages in extending the definition and ontology of 'learning objects' and associated meta-data to include more of the types of objects on which learning depends, especially real world, non-digital elements that support learning and cannot be retrieved on the web. The chapter covers the main factors that demonstrate the need for an inclusive approach to learning objects, how it can be implemented and the implications of such an approach. It extends the learning object economy to include activities, physical objects, human participants, learning structures, and value-properties. Examples of real world non-digital earning objects outside the ICT domain include books, essays, questions, tests, libraries, instructions, discussions, theses, learners, lecturers, curriculum writers, assessors, administrators etc. This inclusive approach extends the basis of the ICT-based Learning Object systems theory in the directions proposed by Harman and Koohang (2005), Wiley (2001), Macromedia (Johnson, 2003) and IEEE (Hodgkins, 2002).

The learning object field is first mapped out in terms of perspectives of six key groups of stakeholders whose jobs are directly impacted by learning object technologies. This high-level overview exposes some of the motivations, forces and factors that shaped the development of the current stages of learning object economy. Following this preparation work, an inclusive approach to learning objects is proposed that includes an extended taxonomy with four additional types of learning object. The practical implementation of this inclusive approach to learning objects using RDF is explored. A brief overview of RDF as part of the Semantic Web provides the background to why it is important to transfer to RDF from markup-based approaches using html and XML. E-portfolios are used as a case study to gain insights into developing systems to address complex learning situations. The implications of the inclusive approach are explored in terms of integration with other institutional resource management systems. Taken together, these issues open up the debate about how power relations and hegemonic factors associated with different protocols and models of learning object architecture strongly shape the control of the learning object economy and who profits from it along with control of technological choices for its implementation.

The Chapter concludes by summarizing the reasons for urgently making a transition to an inclusive perspective on leaning objects that are actualized via RDF and RDF/XML as the primary framework for its organization and for institutional and system interoperability. Three key challenges for future development of the learning object economy are identified.

Introduction

This chapter presents an *inclusive* approach to learning objects that extends their role beyond 'learning content' to include *all* the activities, processes, values, structures and roles associated with learning. To better understand how this inclusive approach applies across the fullness of teaching and learning contexts, the learning object educational landscape is viewed in this chapter through the triple lens of constituent orientation analysis, systems analysis and portfolio-based education.

This inclusive approach emerged from review of the ways that many factors central to gaining the benefits of ICT-enabling education are overlooked by dominant perspectives on learning object theory (see, for example, Wiley, 2001). The application of an inclusive approach incorporates all the factors that impact on the provision of learning and education in public education contexts, including those relating to administration, human roles, value-related factors, evaluation, and the two-way complex of human interactions involved in learning processes. This contrasts with the foundations of many current approaches to developing learning object systems. For example, the military via the US Dept of Defense has been strongly driving the development of learning object standards via the Advanced Distributed Learning initiative (ADL) and the associated Shareable Content Object Reference Model (SCORM) developed by ADL (ADL, 2005a, 2005b) Criticisms of the military basis of learning object systems are it does not match well to real world civilian and public learning situations because of its foundations on the hierarchical command perspectives and the economic influence of US military training interests (Friesen, 2003).

The chapter first reviews the relationships between learning objects, their architectures, teaching and administration activities via six of the main perspectives found in the learning object literature to give insight into the structure and underlying priorities of the learning object literature. The chapter then describes a broader more inclusive model of learning objects and introduces a new 'six-element learning object taxonomy' that effectively adds five new types of learning object in addition to the conventional 'learning content' object. For practical implementation of this inclusive approach to learning objects in computer-networked environments, we turn to the W3C's Resource Description Framework (RDF) with RDF/XML. The chapter outlines the structural reasons why there are significant problems in creating learning object systems that are based on managing meta-data via markup-based approaches at page description level e.g. by html and XML. In this context, attention is drawn to the many other advantages of using RDF rather than XML as the basis for managing learning object meta-data and supporting the extension of the idea of learning objects into other aspects of learning. For example, RDF-based systems can use multiple vocabularies, each of which can be defined externally to avoid the need for a fixed pre-defined model of learning object properties that presume knowledge can be pre-categorized. RDF is also well-suited to bridging the interface between mixed technologies particularly those involving new forms of mobile device that are emerging as central to involving young people with learning systems (Anderson & Blackwood, 2004) through the specific W3C CC/PP device focused generic framework (Manola & Miller, 2004). A fuller description of RDF is available in the RDF Primer located at http://www.w3.org/TR/rdf-primer .

The chapter then outlines how complex e-portfolio systems offer a roadmap for improving learning object systems and support the development of the inclusive approach to learning objects in line with proposals by Wiley (2001), Harman and Koohang (2005), New Media Consortium and Macromedia (Johnson, 2003) and the IEEE definition of learning objects that include non-digital elements that contribute to learning (Hodgkins, 2002). E-portfolios are an important reference in exploring new directions for learning object systems because portfolio-based education is a well-developed educational approach that provides a coherent framework capable of containing, and addressing, a wide variety of information-based learning and education approaches, and addressing many shortcomings of more traditional learning modalities (Biggs, 1997; Hutchins, Sims, & Cooper, 1999; T. Love & Cooper, 2004).

In essence, a portfolio is a structured container that includes meta-descriptions of its contents in terms of a range of factors such as learning outcomes, strategies, roles, performance indicators, analyses, evidence, communication skills, reports, reviews, and other elements of learning interactions. It is also an educational format whose variations have been identified as beneficial across a wide range of learning scenarios including: primary, secondary, graduate and postgraduate education, in-service training, continuing professional development, competency based education, and lifelong learning (Cooper, 1999). E-portfolio systems reveal and resolve many issues that are not well addressed by less complex models of learning that focus primarily on transmitting learning content to students. Learning object theory that fully addresses the complexity of on-line portfolio-based education and assessment will also address all those modalities of education that can be encapsulated within portfolio containers.

The chapter discusses how this inclusive RDF-based perspective on learning objects offers benefits in integrating inclusive learning object systems with other institutional systems and managing power and control issues in the development of learning object economies.

Six Perspectives on Learning Objects and Learning Object Architectures

In virtual learning environments, learning objects are building blocks arranged in architectures to facilitate learning. There are many approaches to learning, and, hence, many ways in which learning object architectures can be conceived.

The learning object literature defines learning objects and related concepts in a wide variety of ways. The lack of agreement about definitions of learning object concepts has been widely documented in reviews prefacing many texts discussing learning objects (see, for example, Center for International Education, 2001; Polsani, 2003; Smith, 2004; Wiley, 2001). Discussion of these issues has been dominated by attempts to identify 'what a learning object is' on hegemonic and linguistic grounds; by issues of epistemological integrity or completeness of concepts; by critiques of technological issues related to computerizing learning objects; and by issues of relating to how learning objects are used. Part of this confusion has been attributed to a specific problem of terminology. The phrase, 'learning objects' comprises two words combining conflicting epistemologies. The idea of an 'object' is tied via 'object-oriented programming' to a tightly defined programmatic discourse and explicitly defined set of concepts. In contrast, the idea of 'learning' is much looser, particularly where learning is regarded as a subjectively defined experience that is not easily rigidly defined.

It is illuminating to view learning object discourses in terms of the constituencies and stakeholders who are directly interested in building value for themselves and others through developing a 'learning object economy'. Constituent orientation analysis describes how perspectives espoused by powerful constituents shape the discourses and conceptualization of ideas: in this case of learning object concepts, theories and practices.

From the viewpoint of constituent orientation analysis, a review of the learning object literature and theory discourse indicates that they are strongly shaped by six perspectives:

- Military trainer perspective
- Teacher perspective
- Learning systems designer perspective
- Librarian perspective
- Computer systems designer perspective
- Education organization manager perspective

The differences between these six perspectives, and their associated views of learning objects and learning object architectures, reflect the reality that each is partial - like the views of the six blind men identifying an elephant in Rumi's Masnavi (Arberry, 1993). Each constituency group creates a discourse and describes the learning object situation in ways most obvious to them. Constituency orientation research (see, for example, Tellefsen, 1999; Tellefsen, 1995) shows that each constituency's discourses, concepts and theories reflect their underlying interests, their habits of thought, the perceived benefits to themselves, and the limitations of that constituency's viewpoint. The learning object theories, analyses and proposals constructed from each constituency's perspective are defined, consciously or subconsciously, in ways that maximize benefits to them, maximize their opportunities for innovation and beneficial change, and maximize their learning within the limitations of each constituency's perspective.

A military trainer perspective: The funding for military and aerospace development of learning object systems dominates the development landscape and has strongly influenced the standards for civilian learning object systems, for example, through ADL's sponsorship of SCORM. Culturally, the purposes of military training are reflected in these standards for learning object systems and the management of meta-data for learning objects. The military environment is one of command and hierarchy. Commands are intended, in most cases, to result in specific responses. In a military educational context, there is increased attention to the identification of a single correct solution. The underlying metaphor is of 'person (usually male) as machine' where the intention is to train people to act with the predictability of machines. This may be appropriate to the potentially life and death environment within which the military operate but is usually not the aim of most public civilian education systems. Architecturally, learning object meta- data for military education contexts is expected to return specific objects that are explicitly defined in advance through a closed meta- data property vocabulary. The highly structured, hierarchical nature of military knowledge and processes are reflected in highly structured, singular, authoritative (rather than non-authoritative) meta- data and learning object architectures.

In a specifically, military education context, learning object architecture is also shaped by additional security required in terms of controlling access to meta- data and learning objects, to search and response communications, and to user access. These military security requirements typically exceed what is provided by commercial digital rights management processes and architectures, and copyright laws.

The strong influence of military culture in standard setting for learning object systems raises the question 'What adaptations are required to military-focused learning object systems and architectures to make them more suited to the purposes and contexts of civilian education systems?'

A teacher perspective: A teaching perspective on learning objects echoes the conceptual base of teacher education. It focuses on the chunking and reuse of snippets of information structured in a similar manner to encyclopedias, learning plans, teaching aims and objectives, and curricula. Seen from a teacher's standpoint, the value gains offered by learning object systems include reduction of teachers' workloads, and improved support for the assembly of courses, course plans and lesson plans, teaching material and lessons for local or distance use. These systems may also potentially offer teachers guidance in drawing up lessons or curricula plans through the automated identification of learning material that sits well in combination. Learning object systems offer these improvements by facilitating rapid access to the largest possible amount of material through easy-to-use search technologies.

From a teacher-focused perspective, a primary architectural concern is that the learning object 'chunks' of content are of an appropriate size. It is important that learning objects are not so big that they introduce spurious extra content. It is also important that they are not so small that lesson and curricula building becomes over-fiddly and inefficient. In between these extremes, architectural concerns centre around the copyright, legal and ownership issues relating to the original physical instance in which the content was published, e.g. the film, web page, books or book sections in which they first appeared. Other architectural concerns, for example relating to technical issues, are secondary and in many cases irrelevant.

A learning systems designer perspective: Learning systems design focuses on teaching and learning processes. Many would argue that teachers are in the same constituency as learning systems designers and that a curriculum is a learning system. Following this line of thought, the teacher perspective and the learning systems designer perspective collapse into one category. In the simplified form found in much of the learning object literature, many of the discourses of teaching and learning systems design are similar and follow transmission/banking models of education. That is, teachers transmit learning content defined in lesson plans and curricula to students for them to bank away in their brains. The simplest learning object approaches align with this transmission/banking model of learning design and combine cataloguing and indexing of learning object content chunks with screen-based interfaces through which learners can interact to be transmitted 'learning content' for them to bank in their minds. In transmission/banking approaches to education the *teacher* or *learning system designer* decides what information the learner needs.

Many learning systems designs involve more complex problem-based learning (PBL) and constructivist approaches to education. In PBL and constructivist approaches, the *learner* chooses which learning content to access, usually in response to problems posed by the teacher or, in the case of professionals undertaking continuing education, by the circumstances of professional practice. This has significant implications for the ways meta-data on elements of learning content are defined and managed because the categorization and management of meta-data must facilitate learners, rather than educators, in making choices about the learning content they access.

For learning systems design professionals, learning object architectures echo learning design theories. The literature indicates that learning design theorists look to the architecture of learning design process models as the basis for computerized system models relating to 'learning objects' and their processes, and theories about them.

From a learning design perspective, a strong complaint about contemporary learning object approaches is they neglect issues central to learning design (Wiley, 2001). Several aspects of learning process important to creating learning designs cannot be implemented using the concepts, definitions and relationship structures of teacher, librarian or object-oriented computer programmer perspectives on learning objects. The learning design constituency position has three critiques of contemporary learning object approaches. The first is learning object theories that focus on making available to the learner 'chunks' of learning content are insufficient for learner autonomy and tacitly impose transmission/banking models of learning rather than complex models of learning such as PBL. The second is the extensive body of knowledge, research and research findings developed in learning design fields, which would be expected to be foundational to learning object systems, is not reflected in learning object standards or literature. The third is the standards for learning object meta-data models do not contain fields necessary for meta-data needed to assemble learning content in ways that reflect the expertise and human knowledge developed by learning design practitioners. These problems derive mainly from the military origins of the standardization of learning object protocols and the widespread focus on storing and managing learning object meta-data by markup at page description level, e.g. through html keywords or XML.

A librarian perspective: The focus of the librarian perspective is on cataloguing and ordering the things in which information is encoded. That is, a focus on cataloguing learning content in terms of the 'containers' in which it is held or was originally published. The gains from using learning objects are in increasing the efficiency and effectiveness of the manual or automated processes by which large bodies of learning content, encapsulated in 'containered' chunks containing multiple sub-elements of learning content, can be indexed and searched.

Architecturally, the librarian perspective is similar to the teacher perspective, though with increased emphasis on the original physical instance in which learning content was first composed, e.g. books, videos, images, and websites. This emphasis reflects librarians' awareness of legal issues concerning rights management, ownership of intellectual property and the complexity of ownership and access issues around published instances. This reflects librarians' awareness that larger learning objects such as books and films typically contain multiple elements of smaller learning content objects of an appropriate size for use in lessons and courses, and that intellectually and conceptually these multiple small learning objects relate together as part of, and within the contexts of, their larger whole.

Computer systems designer perspective: The computer systems designer perspective on learning objects situates computer systems, computer and networked information theories, and systems architectures, centre stage. For this constituency, gains and benefits derive from extending the scope of the 'tools of trade' of object-oriented modeling and programming into the new arenas of learning objects and their management. Extension of object-oriented methods into learning systems gives hegemonic control of future value development in learning object economies to the computer systems specialists and organizations defining the protocols, software systems and structure by which learning objects and their metadata are encoded, managed and accessed.

Different factions in this constituency reflect and shape a tension between business and public interests. On one hand, is the faction supporting the proprietary control of learning object system protocols by a small number of oligopolistic organizations that stand to benefit commercially from this control. On the other hand, are organizations such as the W3C and Open Source organizations that are establishing and promoting frameworks and architectures and conceptual structures intended to minimize the factors supporting oligopolistic control of learning object economies. This situation is a source of tension between and within standard setting groups such as ADL, SCORM, IEEE, IMS, and OSPI.

From the perspective of computer system design specialists of both camps, architectural issues are central. The requirements for defining learning objects and related elements are simply that: a requirement to define objects as software entities shaped by program code and data. The recursive hierarchical nature of inheritable properties of objects in multi-layered object-oriented contexts within epistemologically coherent and abstractly expressed architecture is relatively independent of object types. In practical terms, items of architectural interest relate more to the choice of protocols, programming languages, data space, database structures, and their implications for hardware issues such as the size of servers, required storage, bandwidth, and server load distribution.

Education organization manager perspective: The central roles of the education organization manager constituency are taking responsibility for education and teaching provision, and managing of the associated resources, administration and costs. The central aims of this constituency, in learning object terms, are to maximize benefits from using learning objects and learning object systems in terms of economic and resource management, and institutional competitiveness, whilst maintaining learning outcomes at an acceptable level. These aims can be achieved in different ways. For example, learning object reuse can obtain reductions in human resources and assets needed for face-to-face teaching. The use of learning objects can also be advantageous in improving status-supporting outcome evaluations through access to a better pool of learning content. Learning object systems can also offer this constituency benefits through improving course consistency, and improved alignment of learning processes with students' expectations and lifestyle via online delivery of learning content.

From a learning organization manager's perspective, the primary architecture concerns relate to the learning object architecture's contribution to improving institutional outcomes; and reducing capital costs of systems and software, cost of subscriptions to access repositories, costs of developing, managing and transitioning to learning object systems and reducing the cost of contributing to learning object metadata.

An Inclusive Perspective on Learning Objects

Learning is a complex activity. Learning processes involve a rich combination of activities. A full and inclusive understanding of learning must include elements such as dialogue, feedback, learning by example, problem-based learning, the politics of institutions, and relationships with professional bodies. An inclusive perspective is more than the transmission and banking of learning content in a students' heads. Learning occurs in the complex interplay back and forth between teachers/lecturers and students and those involved in administration and management of teaching and learning support services. In addition, an inclusive approach encompasses the economic considerations associated with education, the objects and processes associated with economic value creation, and all those additional objects, processes and measures/criteria necessary to fulfill the purposes of education and learning.

An inclusive perspective in which learning objects are regarded as representative of elements of a rich, complex, inclusive learning process includes more entities than ‘learning content’. It requires the inclusion of additional *types* of learning objects. Some of these learning objects are *real*, i.e. not in digital form, such as humans, books, and discussions, although descriptions about them and representations of them may be digital.

Examples of six additional *types* of learning object, in addition to the ‘learning content’ learning objects are shown in Table 1.

Table 1: Taxonomy of types of learning object for inclusive approach to learning object systems

New Types of Learning object	
Knowledge content learning objects	e.g. elements of a syllabus
Structural learning objects	e.g. test, essay, book, presentation
Activity-based learning objects	e.g. discussion, evaluation
Role-based learning objects	e.g. examiner, student, administrator
Operation-based learning objects	e.g. objects that describe processes, rules and relationships
Values-based learning objects	Learning objects relating to abstract human values in the areas of e.g. ethics and aesthetics,

Practical items associated with this inclusive complex of learning activities can range from simple to complex. An inclusive perspective on learning object architectures includes services such as:

- Bulletin board
- Online provision of tests and problems
- Online examples of solutions
- E-mail communication between students.
- Recording of discussions and debates between students
- Private and public reflective journals
- Access to learning content about rhetoric and debating.
- Submission of learning evidence services
- Assessment services.

Learning contexts strongly shape choices of learning object architecture. For inclusive approaches to learning objects that include learning contexts in which learners identify their choice of learning content, there are significant advantages in maximizing associative meta-data connections between different learning content objects. For example, meta-data for a type of mushroom may be associated with different types of food, fungi, wood rot, a color, fairies, a pun ('much room'). Architecturally, this high level of flexible meta-data enabled interconnection between learning content is associated with multiple property vocabularies, independent property generation (i.e. anybody can generate properties) and architecture structures that support searches that typically result in multiple objects being returned in the manner of Google.

The positive implications of adopting a more inclusive and extensive perspective on learning objects as described above are manifold. From a learner's perspective, they offer improved integration between the multiple different aspects of their learning-focused relationship with an educational institution. From the perspectives of educators, learning designers and education organization managers, using an inclusive approach to learning object systems helps with bringing together all the resources necessary to teaching/learning success. From a whole organization, larger scale perspective, the potential for integrating inclusive learning object systems with other institutional systems offers the possibility of improved effectiveness and efficiency of learning and education processes through connections between education and interdependent support processes and though avoiding local sub-optimization. It is argued later in the chapter that RDF, Owl and RDF/XML offer the most appropriate programmatic framework for integrating learning object systems with other information systems within an education organization.

The inclusion of the different aspects of learning, its administration and relationships with other institutional systems using a more complex learning object taxonomy also offers the opportunity to classify learning objects in ways that make sense in terms of technology choice. For example, it would be helpful in terms of managing server-based technology to identify and differentiate between learning objects that are used more frequently; must be processed quickly; have high storage needs; require fast access; or need additional software for conversion. Classification of learning objects in these additional ways relates them directly to the network resources and in turn to technology choices to provide those resources within a coherent software framework. RDF offers the potential to describe learning object resources in these different ways later.

Taken together, the inclusive approach to learning object systems offers a basis for extending and integrating learning object systems deep into education organizations to produce value for multiple stakeholders and constituents, and in turn extending the remit of the learning object economy.

Benefits of using RDF and OWL over XML

The dominant focus in the recent literature relating to computerized learning systems has centred on the idea of learning objects as chunks of learning content that can be reused by being combined in different ways with other learning objects for different teaching and learning situations (Alvarado-Boyd, 2003). Typically, learning object systems depend on learning objects being attached to pre-defined 'learning object meta-data' (LOM) that can be indexed and queried by a learning object management system (LMS). The LMS provides the infrastructure for course designers and learners to search for and enable access to learning objects and hence to learning content. In the most common approach, meta-data is incorporated into, or wrapped around, learning content objects using markup languages. Examples of this approach are the inclusion of meta-data in html web pages using Title, Keyword and Meta Tags and embedding metadata in Macromedia Flash files. At a larger system level, learning object meta-data insertion and management has focused on XML-based approaches in which learning objects are located in learning content databases. In terms of the inclusive model of learning objects described above, a limitation of this markup-based approach using html/XML is that they are restricted to learning objects that can be stored digitally with their meta-data and be network accessible.

Taking a systems perspective on learning object systems suggests there are significant systemic structural problems with the use of XML and other markup languages as the primary basis for codifying learning object meta-data for learning object management systems. In the main, these problems emerge as different aspects of poor interoperability at all system levels.

Broadly, the problem relates to locating standardization efforts at the lower system levels. Typically, markup-based approaches to meta-data focus on building standardization and interoperability at page-description level rather than at the level of over-arching system frameworks.

Where standardization attempts are focused on the lower levels of the system, improving interoperability between units, courses, servers, networks and institutions requires several strategies that are difficult to implement, and which structurally add to the overall problem. Addressing the more obvious problems of coding meta-data via inline XML and html markup requires that learning object content and page elements have meta-data applied in consistent pre-defined and pre-structured ways in order that it can be consistently machine readable. In turn, this requires tightly specified, pre-defined and accurately applied meta-data vocabularies. In addition, managing interoperability between different LMSs, different networks and different institutions has required ongoing development of multiple middleware, database and communication standards many of which are proprietary. All of these are problematic for learning content whose meta-data classification is emerging as time passes or that requires being categorized with meta-data in a variety of different ways.

Addressing the problem of interoperability is complex because it involves a variety of technical, human, conceptual, educational and informatic considerations. Systems analysis tools such as System Dynamics are useful in this context because they can include a variety of perspectives (Belyazid, 2002; Forrester, 1998; Repenning & Sterman, 2000; Wolstenholme, 1990). Ashby's Law of Requisite Variety (see, for example, http://pespmc1.vub.ac.be/ASC/LAW_VARIE.html and http://www.cybsoc.org/ross.htm) is of particular relevance to analyzing the current trajectory of learning object system development. The Law of Requisite Variety predicts that to be satisfactory, the complexity of learning objects systems must necessarily reflect and echo the variety in human learning and the variety in the contexts in which the learning object systems function and interact.

From the perspectives of Ashby's Law of Requisite Variety, it is problematic to attempt to propagate standardization upward from the page content level via markup languages when variability occurs at many levels and in ways that are not addressed by page level standardization. In managing variety, the markup-based approach is essentially 'back to front'. The possibilities for control at page-description level is insufficient to produce a stable functioning interoperable learning object system because the variety is insufficient to cover the potential variety across and between different learning objects, courses, learning designs, software systems, disciplines, organizations, networks, and other technical, virtual and real institutions.

The transition to using XML rather than html appears to be an improvement and help resolve the situation because it increases variety at the page description level. In fact, at a whole system level, the gains offered by using XML and XHTML are limited. XML was designed for commercial systems of tightly controlled variety in which a limited number of types of objects are transacted in a closed number of ways with the transactions being undertaken close to page level. In contrast, learning object systems are high variety systems. Using XML in learning object systems appears to offer benefits initially where control is being attempted from page-description level upwards because it increases variety in the communication system at the page description level by allowing meta-data about objects to be included more easily over a slightly more complex variety of contexts.

An effect of using XML at page description level to manage meta-data, however, is to require additional systems to attempt to control variety at higher levels in the system, for example, variety due to differing uses of the same object, differing higher level classification systems, different forms of machine parsing engines with different parsing approaches, differing learning object data structures in different organizations and different computer systems, and even differing interpretations of the XML standards. It is reducing the extensive numbers of problems of variety at the higher levels that the current intensive and expensive effort by organizations such as ADI, IMS, IEEE, and OSPI are hoping to address by additional multiple mid-level standards such as the use of SCORM. Across the learning object economy, the addition of these systems increases the variety overall that needs to be absorbed. That is, attempts to resolve the structural problems by using XML plus additional systems tend to result overall in increased variety and hence increased complexity, weaker interoperability and increased dependence on incompatible proprietary formats each addressing different problematic aspects of standardization. These additions will in turn require more standards to address their new input of variety until eventually the complexity of the standards and variety controlling systems matches the variety in the whole system. This is potentially an open-ended problem because the system is effectively unrestrained at upper systems levels.

This suggests that continuing to develop Leaning Object Systems and meta-data management systems based on XML and related markup languages operating at the lower system levels will continue to result in problems due to a lack of consistency across the upper level frameworks within which meta- data describing resources are described, interpreted and used. That is, the underlying structural weaknesses of XML-based learning object systems will continue to produce problems of incompatibility between systems, continue the problems of lack of flexibility in responding to change and to new insights, and the lack of scalability in processes. These systemic problems with the use of XML and other markup languages have not yet been widely acknowledged by the learning object development community.

The problems of interoperability associated with weaknesses in XML and other markup languages in controlling variety are, however, substantially resolved by the Semantic Web infrastructure. The Semantic Web is well suited to addressing and resolving the issues presented by XML-based and other markup-based LOSs that focus on managing meta-data at the page description end of the system hierarchy. Several areas relating to learning object systems that the Semantic Web is particularly well-suited include (Koper, 2004):

- Development of Web-based courses that are flexible, problem-based, non-linear, incorporate multimedia and are adaptive to learning their characteristics.
- Preserving and sharing knowledge about learning designs to build shareable catalogues of effective learning and teaching patterns
- Automation of the instantiation of new courses in Learning Management Systems
- Using software agents to support learners and educators in managing workflow in teaching and learning
- Automation to improve learning design adaptation to individual learners.
- Sharing and reuse of course components to improve efficiency of course development
- The use of semantically labeled content in the creation of more advanced, more complex, learning designs that are consistent.
- Performing research into learning design by using semantic information to improve the correlation between learning design structures and their real-life use

The Resource Description Framework (RDF) was created by the W3C organization for managing semantic meta- data in Web environments. It satisfies criteria of *independence* (anyone can define properties), provides an effective means of *interchange* (via RDF/XML), and is *scalable* to extremely large numbers of objects and properties through its simple syntax.

In essence, using RDF as a framework controls variety from the top down. In addition, it increases the variety of the system and its communication channels by enabling relatively uncontrolled variety in the software systems at page level. RDF specifies standards and interoperability at network level, and as a framework for interoperability propagates standardization via simple graph-based ‘triple’ protocols downwards to the page level where it can be efficiently actualized via, RDF/XML an RDF-based variant of XML that integrates well with existing XML page descriptions.

In practical terms, RDF has several key aspects. It allows the separation of content describing learning objects, i.e., metadata, from the objects themselves. It resolves many of the problems of annotating learning content with meta-data because it allows the integration of different forms of meta-data; provides a smooth transition to consistent vocabularies as and when they are available and appropriate. It also provides graceful resolution of inconsistent meta-data, and relative avoidance of incompatible meta-data. Important practical benefits from using RDF to control variety in learning object systems include that it is designed at the outset to be machine processable with its statements consistently parsed by standard readers; it is designed to be scalable; it allows seamless integration of physical, real world physical learning objects with digital learning objects; it supports transferability of learning objects between different institutional contexts; and it accommodates different qualities and structures of meta-data.

The syntax of RDF is graph-based with a basic unit or 'triple' comprising two nodes and the arc between them. These represent **subject, predicate property** and **object**. The **subject** is the focus of the statement, and the **predicate** describes a **property** of the subject with a property value known as the **object**.

For example, the statement 'http://www.XYZ123.com/index.html has an author whose value is Mary Jones has:

Subject: URL http://www.XYZ123.com/index.html

Predicate: the word "author"

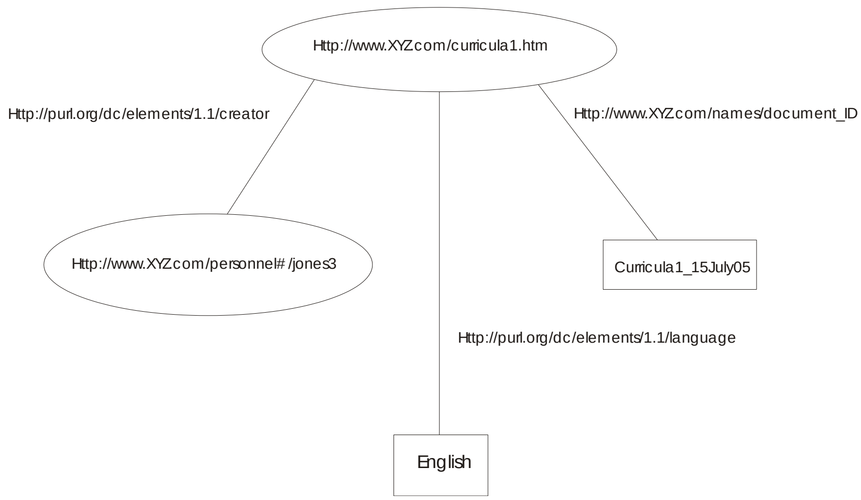
Object: the phrase "John Smith"

The RDF framework enables this graph-expressed semantic information to be used by different applications without loss of meaning using RDF processing tools.

RDF uses *Uniform Resource Identifier references* (URIs) for describing resources in terms of simple properties and property values. A URI can be created to refer to ***anything*** including,

- Network-accessible things, e.g. electronic documents, electronic services, network enabled/accessible resources.
- Things that are not accessible via computer networks, such as humans, businesses, and physical books.
- Abstract concepts such as the idea of "author".

The primary representation in RDF comprises simple three-part graphs of nodes and arcs which consist of a node for subject and a node for the object, joined by an arc representing the predicate or property. In converting to a machine processable form, RDF graphs can be written as triples of subject, predicate, and object for each arc. For example, the graph below has three arcs each of which can be represented in triple notation.



The above graph can be written as

< http://www.XYZ.com/curricula1.htm > < http://www.XYZ.com/names/document_ID> "Curricula1_15july05".
< http://www.XYZ.com/curricula1.htm > <http://purl.org/dc/elements/1.1/creator> < http://www.XYZ.com/personnel#/jones3>.
< http://www.XYZ.com/curricula1.htm > <http://purl.org/dc/elements/1.1/language> "English".

The combination of the RDF graph/triple format for descriptive statements means that properties are resources themselves and hence can themselves be subjects of RDF graphs and have properties and similarly be objects of RDF graphs as values.

The triple statements that describe each RDF graph can be compacted using a variety of approaches that utilize qualified names and URI defined namespaces and vocabularies through the RDF/XML syntax for describing RDF graphs. RDF retains the use of XML in page presentation of object and property information via the RDF/XML programming language which provides the means by which RDF graphs are expressed on the Web. RDF/XML, like html, is machine-processable across the Web. By these means, RDF provides a consistent simple semantically coherent high level framework that is scalable and straightforward to parse by machines (Bray & Brickley, 2001).

Using URIs to describe properties and relationships as well as objects allows RDF to describe practically anything and the relationships between them. In learning object system terms, RDF supports the inclusive approach proposed earlier because its use of URIs allows the inclusion of real world non-digital learning objects within learning object systems. Using URIs also provides the means to distinguish different types of properties that might involve the same term in different applications. For example, "publisher" may be a business name or be a variable field in different circumstances. Using different URIs for each separates the meanings. For the future, ontology languages such as OWL extend RDF by providing additional machine-processable semantic information about objects that is purposed to more closely resemble real world meanings (Ford, 2004; Manola & Miller, 2004).

An additional benefit for developing learning object systems is that RDF is intrinsically extendable, i.e. anyone can write property and value data about objects. RDF refers to a collected set of properties as a **vocabulary.** Different vocabularies can be freely mixed in RDF graphs. Using a common namespace URI for the location of collections of vocabulary terms simplifies coding but is not essential. Unlike XML, RDF does not provide a vocabulary itself, nor require specific vocabularies to be pre-defined. Instead, RDF provides the facilities to describe objects and properties and the relationships between them and provides the framework within which individuals and organizations may choose to define user-defined and shared vocabularies. BY these means the RDF framework reduces variety at higher system levels whilst providing the basis for individuals and organizations to increase variety through vocabularies so that the system variety can match that of the learning situation.

In terms of integration with other information and management systems, RDF supports a smooth transition to other systems outside the immediate learning object arena. This is because most physical systems describe things in ways that are of essence in entity-relationship formats. RDF triple notation is a machine-processable way of managing entity-relationship data and can interface with other information structures encoded as records in databases (flat file or relational), indexes describing data resources, models expressed in Universal Modeling Language (UML), rows in spreadsheets, and logical statements.

RDF-based systems that impinge on the learning object system arena are emerging (see, www.w3.org/TR/rdf-primer). One of the more significant yet hidden RDF-based technologies supports better use of mobile devices. Mobile devices for browsing the Web have been identified as important in learning contexts by the Joint Information Systems Committee (JISC) in the UK (Anderson & Blackwood, 2004; Manola & Miller, 2004). Mobile devices typically have highly heterogeneous functionality and network connectivity capabilities and are user configurable in terms of the ways they function and present information. Users expect a usable presentation regardless of the device's capabilities, user settings or network characteristics. The heterogeneity and flexibility can result in less-than-optimal outcomes for the learner. Problems of mobile devices are addressed by an RDF-based composite capabilities/preferences profile (CC/PP) that provides a framework for others to define interoperable vocabularies to manage components and attributes. Examples include the User Agent Profile by the Open Mobile Alliance and the WAP Forum's Multimedia Messaging Service Client Transactions Specification. No single organization is likely to create a dominant schema, and new properties can be included as and when they become available.

Other practical examples of RDF systems with a bearing on learning object systems development include PRISM (Publishing Requirements for Industry Standard Metadata), Dublin Core Metadata Set, RSS 1.0 and XMP. PRISM was created by publishers for re-publishing content in different ways, and emphasizes discovery, rights tracking, and end-to-end metadata to enable easier searching, improve tracking and definition of user rights across different contexts and provide persistence of meta-data across different publishing systems. The Dublin Core Metadata Set (available http://dublincore.org/documents/dces/) manages meta-data about documents in ways that are easy to automatically collect by web robots and easy to create by publishers who are not technical specialists. RSS 1.0 is an extensible RDF vocabulary for describing web information for syndication mainly through on-line aggregators and via individual desktop readers. XMP is an RDF-based model from Adobe for embedding meta-data in PDF files, HTML and SVG/XML, images in JPEG, TIFF and GIF, and files with proprietary Adobe formats for Illustrator (Bray & Brickley, 2001).

Learning Objects and Portfolio Systems

The proposed inclusive approach to learning object systems offers an opportunity to draw on insights from complex portfolio-based approaches to education that provide additional understanding of processes, relationships and problems associated with a variety of education modalities. There is a close fit between e-portfolios and the above inclusive model of learning objects systems because of the object-based nature of portfolios as containers of sub-elements.

Portfolios are successfully used across a wide range of education scenarios in primary, secondary, tertiary and doctoral education as well as vocational education, in service education, continued professional development, authentic learning, constructivist learning, and life-long learning. Portfolios can address many weaknesses of other teaching and learning approaches, particularly in the area of assessment and evaluation where they can address situations that are problematic for conventional ‘single shot’ assessment methods, e.g. when there is a difference in individual sequence and pace of learning development and individuals’ acquisition of professional competence and professional skills. Study of portfolio-based learning systems also reveal issues neglected by the six perspectives described earlier.

There is a slight confusion in the online portfolio literature. The meanings of ‘portfolio’, ‘webfolio’ and ‘e-portfolio’ often overlap. For some authors, an e-portfolio is simply an electronic copy of a paper-based portfolio in Word or PDF format, whereas a webfolio draws on all the functional advantages of on-line environments (see, for example, D. Love, McKean, & Gathercoal, 2004). In contrast, other authors regard the situation as exactly opposite with webfolios being regarded as electronic copies of paper portfolios whereas e-portfolios are complex products fully utilizing the online environment(Batson, 2002). In addition, a recent review of online portfolios (T. Love & Cooper, 2004) found that many cases of simple portfolios comprised a rebadging of single items of work that would previously have been called term papers and school project essays. In this chapter, the term 'portfolio' will be used to denote all forms of portfolio-like systems and containers, 'e-portfolio' will be used for portfolios that are electronically encoded with the exception of the rebadged single item portfolios, 'hard-copy portfolio' will denote non-digital portfolios.

There are two main perspectives on portfolios. The earlier view was of a simple container of stand-alone items of evidence. The more sophisticated view is portfolios as integrated complex products with additional properties that raise the value of the portfolio and its contents over and above the simple sum of their parts. Traditional examples of the simple portfolio are artists' and architects' portfolios of drawings. In assessing simple portfolios, it is left to the reader to derive an understanding of a learner/practitioner's skills and formative development from the stand-alone items of evidence found in the portfolio.

In educational situations where 'deeper' and more complex learning is intended, complex portfolios offer significant advantages. Complex approaches to portfolios emerged in professional education with its focus on higher professional skills and knowledge, competences, self-directed learning, skill certification, and complex adult learning models. Complex portfolios align well with complex learning models that include learning outcomes, learning strategies, performance indicators, and the creation and collection of evidence that the learner has satisfied specific learning criteria and can demonstrate specific skills. It is for these reasons that portfolios are established worldwide as a primary method of demonstrating continuing competence in professional medical, educational and technological contexts. Added value is contributed by portfolio elements that describe the purposes and roles of the portfolio and provide indexing and commentary that links evidence in the portfolio with indicators of performance, competencies and learning intentions. These complex portfolios may also contain elements that aid with automating the administration and management of the portfolio for all the people who interact with it.

The integration of complex e-portfolios and inclusive learning objects can reach deeply in several directions across learning processes. For example, when portfolios are used in documenting the relationship between evidence and learning this may involve learning objectives, learning strategies, learning activities, satisfying learning criteria, understanding what is to be learned and what has been learned, and which skills and competences demonstrate learning and why. Portfolios and inclusively based learning objects in online environments can provide a structural basis for automating many educational processes in the areas of assessment, course administration, and the planning of learning activities.

In practical terms, a complex e-portfolio-based system has several components that come under the category of inclusive learning objects. These include the portfolio container itself, which if implemented by RDF or similar frameworks may be multidimensional and multi-modal containing or pointing to digital and physical evidence. It may contain information about itself, about its content, its owner and its purpose, along with a schema of pointers to locations of the different parts of the portfolio (similar to a Table of Contents enhanced by the online context. The two largest groups of learning objects comprising evidence tied to the learning objectives, standards and performance criteria that indicate that learning has been achieved; and commentaries that explain and justify a student's claims that they have satisfactorily achieved the standards described by learning criteria. Both may be supported by learning objects comprising supplementary and peripheral explanatory information such as glossaries or data appendices. The presentation of information from the e-portfolio requires learning objects whose focus is the collation and formatting of evidence and other information from the portfolio for different purposes, for example, in ways that make it easy to read for assessors. Formative portfolios will contain learning objects that describe changes in learning outcomes that reflect the learners' path of increased learning or skill over time. Professional competency-driven learning portfolios will include learning objects that describe the performance criteria explicitly defined by professional organizations. Portfolios used as part of constructivist, authentic and self-directed learning may include learning objects containing discussion and reflection relating to a student's learning, the reasons for exploring particular learning areas and the student's reasoning about how the success of their learning activity is best assessed.

E-portfolios for education professionals and e-portfolio practices in universities run parallel to developments of learning object systems for school and undergraduate study and dominate the e-portfolio literature. A key issue is the role of competencies in learning. Development of reusable competency definitions by the Learning Technology Standards Observatory (LTSO), adopted by IEEE, provides a strong foundation for extending learning object-based professional education and assessment across a variety of fields. Another important issue is building learning systems that have a smooth transition between tertiary education and continuing professional development. One example bridging this divide is use of graduate attributes and PULs (principles of undergraduate learning) in e-portfolios at Indiana State University where capstone courses are precursors to professional competencies (Indiana University, 2004). Another example is the on-line competency-based assessment for the monitored professional development scheme of the Institution of Mechanical Engineers delivered via proprietary SkilSure ® software (www.skilsure.com). A third example of online education transition in a semi-professional arena is the e-portfolios for industry practice/professional practicum for undergraduate Leisure Sciences students at Edith Cowan University (Colyer & Howell, 2002).

Recent research by the authors into e-portfolios suggests the most significant potential gains for e-portfolios focus on administration (T. Love & Cooper, 2004). The capability to administer and manage learning environments is the central role of education programs and learning is crucially dependent on these environments. This suggests that the authors' findings apply also to inclusive learning object systems. Inclusive learning objects systems and e-portfolios offer increased sophistication in administration and hence improvements in learning through providing learning environments better aligned to the needs of learners across all aspects of their learning experience. Trends in e-portfolios support this reasoning. For example, in e-portfolios at the University of Minnesota (Treuer & Jensen, 2003) students learning experience is improved through simplifying administration: information about a student held by the University is replicated to the students portfolio thus improving communication with students. Another example is when students manage their own records through a lifelong possession of learning object-based e-portfolios.

An inclusive approach to learning objects like e-portfolios also offers automation of many aspects of administration. One aspect is the automated production of reports. For the learner these might include automated production of their CV or a list of certificates. For the assessor they might include the ability to automatically create mark lists and associated statistics, mapping a number of learners' relative development across a range of objectives, identification of 'to do' issues, automated feedback reports for future curricula and lesson planning identifying areas in which learners found satisfying the learning objectives less easy, listing which students have been assessed or not.

The interoperability problems of learning object systems are predated by similar problems in e-portfolios. Key interoperability concerns relate to enabling students to transfer seamlessly between campuses, courses and institutions, and for integration of formal education, lifelong learning and professional development. In parallel to learning object systems, the preferred approach has been to focus on establishing a central, secure, complex repository of certification and evidence of competence for each student: the e-portfolio (National Learning Infrastructure Initiative, 2003). As in learning object systems, initial attempts to electronify portfolios focused on converting paper documents into equivalent electronic documents. Standard setting focuses on defining preferred page formatting protocols, of which the primary choices were Word docs, PDF and html. As it became clearer that was problematic in terms of the ways meta-data could be attached to information there was a widespread drive to adopt XML which offered finer grain meta-data description of content. This is the current state of the art. Solutions also appear to reside in a transition to data management based on the Semantic Web and RDF.

Integrating Inclusive Learning Object Systems with other Institutional Systems

RDF-based approaches specify high-level criteria for interoperability of systems to manage resources. The proposed RDF-based inclusive approach to learning objects extends learning objects into non-digital, real-world domains. It brings inclusive learning object systems into the same territory, in informatic terms, as other institutional computer-based systems such as: human resources systems, research and research support systems, maintenance systems, financial systems, management systems, asset and resource management systems, as well, obviously, as training and educational support systems, governance systems, marketing & sales systems, customer relationship management systems, evaluation systems, strategy and planning systems. Using RDF offers the potential to bridge between these systems.

There are several potential and significant benefits to be gained from linking together inclusive RDF-based learning object systems with the other management information systems of education organizations. The first is the potential for direct synergetic improvements in efficiency and effectiveness. For example, the administration of staff and resources required to implement a learning program requires integrated administration of learning object systems of course management, human resources management systems and asset management systems, along with technology management systems e.g. to manage bandwidth and server load. Initiation of an education program using learning objects acts as a driver for changes in these other systems. Integration between systems offers possibilities for automation, reduced administration, simplification of processes, reduced management overhead, reduced errors and a reduction in systems failures caused by failures of interoperability. The second reason is that improvements in overall integration facilitate whole system optimization at 'whole of organization' level. That is integration of learning object systems with other institutional systems maximizes the opportunity to fulfill the vision, mission and strategy agendas of top management through reducing problems caused by local sub- optimization of individual education and learning processes at the expense of broader organizational aims and objectives. The third reason is that of ensuring that all the components of a viable organization as defined by Beer's Viable System Model (Beer, 1989) are in place. That is, ensuring that all five information, auditing and management pathways are functioning in ways that guarantee the organization itself is a viable system. Coupling inclusive learning object systems and other organizational systems in line with Beer's viable system model provides the means of improving education organizations' responsiveness to change, particularly at their interface with students and the educational environment. This helps establish stability, improve management processes, improve strategic planning, reduce management and administration costs, assist with the early identification of problematic situations: and automate information flows.

The case for integrating inclusive learning object systems with other systems of education organizations are supported by experience in other fields. The use of Enterprise Resource Planning systems (ERP) and Product Life Management systems (PLM) indicate that whole of organization benefits are realized when specialized systems such as learning object systems are integrated into organization-wide systems in the areas of human resources, asset management, room management, accounting, and operational support. An interesting example of this is the recent integration of computer assisted design (CAD) software into Enterprise Resource Planning (ERP) software. Surprisingly, this resulted in inversion of the overall package structure, in which ERP became a sub-element of the CAD software in a transformation into Product Lifecycle Management (PLM) software (see, e.g. IBM, 2002; SAP, 2002). Similar factors apply in the case of education and learning. It will be interesting to see whether learning object systems subsume education organizations to other operational systems. The proposed inclusive approach to learning objects described in this paper and prefaced by the original IEEE definition of learning objects will support that transition.

The Future Learning Object Economy: Technology and Protocol Choice, Hegemonic Factors and Control Issues

A significant managerial decision for educational organizations using learning objects is whether to commit to markup-based systems using e.g. html and XML with their intrinsic problems or wait until more fully developed RDF-based systems become available. Those developing learning object systems will also have to decide if and when to make the transition to RDF/OWL based Semantic web as the basis for learning object systems.

The outcomes of these choices have a significant potential impact on who will hold power and control in the new learning object economy. Conventional learning object approaches divide the market up between those who create learning content objects and meta-data, and those who supply proprietary learning object management systems. This maps onto the traditional model of data + database management system. In effect, it establishes a duopolistic relationship between two constituencies with very different access to power, control and the value generated by the learning object economy. It is similar to typical author/publisher models. Both data management and publisher' approaches typically distribute power and reward preferentially to those controlling the content management system. Those producing the information are frequently expected to do so for free (as in academic journals) or for a low profit share (as in book royalties). If this model of learning object systems and their management becomes the dominant dynamic, then critical mass issues will likely ensure that power, control and profit will be distributed to a single dominant player or small oligopoly across the learning object system market.

If the learning object economy proceeds into a situation in which it is hegemonically controlled, technology choice is likely to be limited by actions of oligarchic players and self-serving arrangements between them. This follows a well-established pattern between those who generate data or information and powerful software developers who provide systems to facilitate accessing that data. This scenario in future would be expected to reflect a situation with a dominant player in an effectively fragmented market in which non-monopoly players are limited to small niche approaches. Open Source software has been partially successful in addressing this problem, particularly in software for web servers, file and print servers' ftp servers, mail servers, database services, network services customer relationship management software and in learning object systems developed by organizations such as the Sakai project (http://www.sakaiproject.org/).

One of the characteristics of RDF is that it goes some way to frustrating attempts to monopolize the learning object economy. It does this by reducing the hegemonic control that commercial organizations can exert via proprietary standards in the middle and upper tiers of the learning object systems. This suggests there is likely to be some resistance by commercial developers to moving away from markup-based html and XML systems because these potentially offer commercial advantages for increasing profit via hegemonic means.

The inclusive learning object approach based on RDF, RDF/XML and, eventually, OWL, provides a basis for a less hegemonically-driven economy that opens up opportunities for multiple players to exploit their expertise in learning object services provision in ways that can be integrated coherently through the use of RDF and vocabularies. Thus the proposed inclusive learning object approach which includes a wide variety of additional aspects of learning processes as learning objects within a system unified under RDF, offers an opportunity for a more economically equitable playing field with opportunities for real competition at variety of levels of the sort likely to result in rapid technology and software advances. Using RDF to bridge the divide between learning object content and learning object management systems gives the opportunity for technology choice to be open to all hardware systems capable of implementing RDF and RDF/XML.

Conclusions

This chapter has proposed an inclusive approach to learning object systems on the basis of a 'helicopter' view that focuses on the larger scale issues relating to the use of learning objects in online education. This perspective brings to attention the reality that many of the key components that contribute to effective learning are situated outside the simpler models of learning object that focus only on learning content.

The inclusive approach to learning object systems described in this chapter includes real world physical entities associated with roles, processes, values, structures and activities that contribute to learning. This inclusive perspective includes as part of the learning process all of the interchanges, roles, relationships and processes that happen within an organisation dedicated to education. The chapter points to advantages in viewing the contributions of different learning objects as parts of a complex system exemplified by e-portfolio systems.

For implementation, inclusive learning systems are well served by RDF and RDF/XML and OWL. Together these elements provide a practical technical and conceptual basis capable of extending learning object approaches and the learning object economy to include all impacting issues.

This chapter has introduced several new themes in the learning object discourse. It first discussed the learning object literature in terms of six different constituencies, each with their own perspectives and ways of conceptualizing learning objects and learning object system architectures. This drew on constituent analysis to identify the limitations and motivational biases of these six specific constituent groups involved in shaping the learning object economy. Second, it introduced and described an inclusive approach to learning objects that alongside learning content integrates real world objects and processes in the realms of learning activities, processes, structures, non-digital resources, values and human roles. Third, the chapter drew attention to the serious problems associated with encoding meta-data using markup-based approaches with html and XML and meta-data at page description level as the basis for creating learning objects and learning object management systems. We outlined the advantages in moving to address these issues via a transition to RDF and RDF/XML. The chapter drew attention to the benefits of developing closely integrating computer-based learning object systems with other institutional systems within education providers. The case of e-portfolios was then used to derive insights into aspects of the complex characteristics of electronically supported learning. The benefits of integrating inclusive learning object systems with the other resource management systems of education organizations were explored along with a review of the power and control issues evident in the emergence of a learning object economy.

From the viewpoint described in this chapter, the challenges for the future of learning object systems are three-fold. The first is to more clearly establish learning object approaches that focus on civilian and public education with its specific needs, characteristics and purposes of contexts. This requires a significant transition away from the hierarchical, command and control military training perspectives that have strongly influenced the philosophical foundations of learning object system theory and the development of current learning object systems standards. The second is to address the reality of future transition to learning object systems based on RDF, RDF/XML and OWL rather than the current problematic markup-based html and XML-focused approaches. There is likely to be some resistance to this transition because there has been significant investment in a variety of proprietary, relatively incompatible and, in meta-data terms, problematic learning object systems tagged with markup in html and XML. Third is the need to identify an appropriate approach using RDF for integrating civilian learning object systems with the other resource management systems of education providers.

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