Issues of Designing Educational Multimedia Metadata Set Based on Educational Features and Needs

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Abstract

The sharable and reusable multimedia learning objects are very important to avoid repeated efforts among users. LOM-like standards have been widely used to support resource managements and applications. This paper describes the differences between LOM-like standards and educational needs of multimedia learning objects. We classify multimedia learning object types based on educational features and needs, and explain the differences between multimedia and single media learning objects. Existing LOM-like standards lack educational feature descriptions about educational needs, are not easy to retrieve middle-level (e.g., abstract) and high-level (e.g., pedagogy and context) semantics from multimedia learning objects. In order to make existing LOM-like standards and technologies really benefit the teachers, this paper summarizes the issues of designing metadata content structure for storing educational multimedia resources.

Keywords: Metadata, Multimedia learning object, Educational feature, Metadata content structure.

1 Introduction

The sharable and reusable learning objects not only can save repeated efforts in developing learning materials, but also can potentially improve learning quality. Many organizations and departments have defined learning object metadata (LOM) standards composed by bunch of metadata elements to describe attributes and features of learning objects, to support sharing and reusing learning objects. For examples, The Institute of Electrical and Electronics Engineers Learning Technology Standards Committee Learning Object Metadata (IEEE LTSC LOM) and Dublin Core Metadata Element Set (DCMES) are popular standards. There are other LOM-like standards, such as Advanced Distributed Learning Sharable Content Object Reference Model (ADL SCORM), Instructional Management Systems (IMS) Global Learning Consortium (GLC), etc.

Learning content/resource management systems, instructional management systems and annotation tools widely use existing LOM-like standards. We conclude the LOM-like standards' functions as [1-5]

- *Indexing/Archiving*. Metadata can index and archive learning objects by metadata elements, such as keyword, title, classification, and so on. Dublin Core Metadata Element Set is usually used in library for archiving, indexing and searching.
- *Retrieval/Search*. Metadata descriptive information helps data retrieving and searching. For example, if the learning resources are described as IMS, SCORM, and SHOE, then the learning content/resource management systems can automatically generate personalized learning paths [6] and learning resources [7].
- *Sharing and Reusing*. Metadata is a set of unified and pre-defined names which represent learning objects' attributes and features. The metadata makes learning objects sharable and reusable via unified names, e.g., IEEE LTSC LOM [8].
- *Evaluation*. Some metadata elements can describe the learning object's evaluation results. The evaluation not only judges the learning objects quality, but also helps users know if the learning objects are suitable to their learning objectives and characteristics.
- *Interoperability*. The learning resources developed by different teachers and developers (resource developers) can be reused by taking one unit from an author's works and taking another unit from another author's works, users are free to re-arrange and combine any resources which comply to the same standard. For example, ADL SCORM compliant e-learning courses [9] [10].
- *Context*. Metadata can represent relationships among learning objects to support context-awareness learning.

Multimedia learning objects have been increasing with the rapid growth of technologies. Meanwhile, learners are eager to see multimedia learning objects because they are tired of those text and/or picture-only learning contents. Learners like multimedia learning objects because multimedia is attractive and interesting to them. Multimedia learning objects can stimulate multi-sensory learning and give learners impressive memory to improve their learning efficiency [11].

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The existing LOM-like standards are not very efficient in searching and reusing multimedia learning objects. Existing LOM-like standards are also not good in solving multimedia learning objects' integration, delivery, exchange and interoperate issues [12]. The main reason is that one single multimedia learning object may contain many media elements in various types, e.g., text, image, video, audio, audiovisual, animation and 3D. Furthermore, any multimedia type can be stored with different formats, for example, a video clip may be created as/stored into AVI, MPEG, or QuickTime movie format. Different formats create difficulties for users (teachers/developers and learners) in sharing, exchanging, interoperating and reusing multimedia learning objects.

In addition, LOM-like standards lack descriptions for educational needs of using multimedia in learning, education and training. For example, Tom is a learner who likes multimedia learning objects when he learns about science, such as explanations about physics or chemical. Susan is a teacher who prepares teaching contents for learners. She finds well designed multimedia teaching contents will improve teaching efficiency. Susan wants to find multimedia materials for teaching "total solar eclipse."

She encounters some difficulties in searching multimedia materials. She can only use keywords or titles to search for multimedia resources, e.g., "solar eclipse" and "video clip." She can not find lecture videos made by other science teachers very easily, because the search engine only supports users searching titles and subjects of resources instead of educational features.

She has to go through the searching results very carefully to ensure the multimedia resource she found can be opened and played by her. For example, she can not open pictures stored with Adobe Illustrator (.ai files) and can not play video clips created with mpeg4 (.mp4 files). Therefore, she sometimes can not reuse the multimedia she found due to the two reasons described above. She sends email to John and Jack to tell them the troubles she encounters. John is a developer of multimedia learning objects. Jack is a manager of multimedia resource system. How to make multimedia learning objects searchable and reusable is very important [13-14].

Some multimedia metadata models are used to describe multimedia objects, such as Dublin Core, MPEG-7, P_Meta, and so on. These models have some descriptive metadata elements for multimedia resources [8], e.g., colors and natures, but none of them fulfill all requirements of educational multimedia yet.

This paper summarizes the issues of designing metadata content structure for storing educational multimedia resources by comparing with existing LOM-like standards and analyzing the educational multimedia needs. The summarized design issues can help researchers identify and design educational multimedia metadata set in order to improve LOM-like standards.

Section 2 summarizes existing LOM-like standards and explains their features. Section 3 describes some techniques of realizing and accessing LOM-like standards by machine, including eXtensible Markup Language (XML), Ontology, Semantic Web, and Resource Description Framework (RDF). Section 4 has two tasks: (1) discusses the multimedia learning object types, educational features and needs, (2) compares the requirement differences of metadata between multimedia and single media learning objects. Section 5 summarizes issues of designing metadata content structure for storing educational multimedia resources. Section 6 gives simple conclusions and possible future works.

2 Standards of Sharing Learning Objects

The growth of digital learning objects brings some problems:

- Similar and relevant contents for the same learning topic and/or subject may be distributed at different places. Users have difficulty in searching these distributed learning objects.
- Similar and relevant contents for the same learning topic and/or subject may be created by different teachers and developers again and again. This phenomenon will waste a lot of efforts and money around the world.
- Similar and relevant contents for the same learning topic and/or subject may be created in different formats by authors who use different authoring tools. It is an obstacle for interoperation.

Sharable learning resources not only can solve the above-mentioned problems and allow teachers/developers creating new learning resources more efficiently and decreasing many unnecessary efforts, but also make learning resources referenced and reused for learning, education and training world-widely. Resource managers and developers use LOM-like standards to realize learning resource management and applications including sharing, reusing, browsing and searching.

Metadata has no united definition. The most common definition is "data about other data" [15]. In terms of its various definitions, metadata has following features:

- Metadata is a structured or semi-structured data element set to describe things.
- There are technical metadata and descriptive metadata. Usually, technical metadata elements are low-level semantic which are independent on objects' learning contents. Descriptive metadata elements are mid-level

and/or high-level semantic which are dependent on objects' learning contents.
- Can be used to implement some basic resource management and application functions, such as indexing, searching, reusing, sharing, evaluation, interoperation and so on.
- Can be coded into computer languages, such as eXtensible Markup Language (XML), so that machine can read and understand it.

In summary, metadata is a structured or semi-structured data element set to describe learning objects, and can be understood by both human and machine. The uniformed data elements can be used to solve the problems caused by the diversity of cultural and lingual contexts. Some typical existing LOM-like standards are described in the following sub-sections.

2.1 IEEE LTSC LOM

Learning Object Metadata (LOM) has been developed from 1997 by The Institute of Electrical and Electronics Engineers Learning Technology Standards Committee (IEEE LTSC). IEEE 1484.12.1 standard for LOM concretely specifies data element attributes to describe learning objects [16]. These data elements can be classified into nine categories: general, life cycle, meta-metadata, educational, technical, rights, relation, annotation, and classification.

There are other standards to represent the LOM records and make machines understand the meanings of learning objects, for example LOM Data Model uses eXtensible Markup Language (XML).

2.2 Dublin Core

Dublin Core Metadata Element Set (DCMES) was produced at the metadata workshop sponsored by Online Computer Library Center (OCLC) and National Center for Supercomputing Applications (NCSA) in March 1995. Dublin Core (DC) metadata element set can be applied in any digital resources. Its goal is to provide users a convenient way to discover and retrieve digital resources. On the basis of DC, Gateway to Educational Materials (GEM) and Education Network Australia (EdNA) were founded as well.

Dublin Core Metadata Element Set has fifteen core data elements, including title, creator, contributor, publisher, subject, description, data, resource type, format, identifier, source, language, relation, coverage, and rights.

According to the requirements of learning, education and training, Dublin Core Education Working Group (DC-ED) has been founded. This working group added elements which describe educational characteristics, such as audience, mediator, instructionalMethod, conformsTo, educationLevel.

2.3 MPEG

The Moving Picture Experts Group (MPEG) is a working group of ISO/IEC, namely ISO/IEC JTCI SC29 WG11. The Moving Picture Experts Group (MPEG) develops standards for digital audio and video, such as MPEG-1, MPEG-2, MPEG-4, MPEG-7 and MPEG-21.

Jacco et al. concretely compared MPEG-7 and RDF [17-18]. MPEG-7 is a good metadata model for describing multimedia learning objects, has a broad range of applications, and supports fine grained description of content fragments [18]. MPEG-7 has high comprehensiveness, fine grained representation, structured representation and extensibility. MPEG-7 is not good at describing high-level semantic information [1]. RDF is efficient in describing semantic information, but has interoperability problems due to the applications must be semantic web applications [1].

2.4 MAWG

W3C sets up media annotation working group (MAWG) to define the bridging ontology for different descriptions of media resources on the Internet. Now the ontology is still a draft and is under revising. The ontology is a core set of basic metadata to describe media resources' properties. The MAWG also defines property mappings among existing metadata standards, such as IEEE LTSC LOM, MPEG7, IPTC, YouTube, and EBUCore. The ontology and property mappings can realize interoperability among existing metadata standards and help users managing and searching web resources.

2.5 Comparisons of LOM-Like Standards

Other organizations also define LOM-like standards. Different LOM-like standards are defined based on different requirements of media type and application. According to media types, the metadata standards are mainly classified in three types: (1) text-based resource metadata, (2) audio-based resource metadata, (3) image/video/multimedia-based resource metadata. On the basis of special requirements of different application fields, the metadata standards can be classified in digital library metadata, learning/education objects metadata, geography resource metadata, and digital museum resource metadata, and so on.

This paper mainly focuses on education field and multimedia. The typical learning objects metadata standards are IEEE LTSC LOM and DC. Dublin Core cross-refers IEEE LTSC LOM. Other learning objects metadata standards are localized by referring IEEE LTSC LOM or DC. Therefore the learning objects metadata standards have similar advantages and disadvantages just like IEEE LTSC LOM and Dublin Core have. Table 1 shows the relationships of these learning objects metadata standards.

The typical multimedia metadata standard is MPEG-7. MAWG is the bridge between many metadata standards, such as learning objects and multimedia metadata standards on the Internet. So, DC, IEEE LTSC LOM, MPEG-7 and MAWG are selected to compare as Table 2 shows.

Table 1 Relationships of Metadata Standards

Metadata standards	Refer other standards
DC	IEEE LTSC LOM
IEEE LTSC LOM	DC
IMS LRM	IEEE LTSC LOM
ISO IEC JTCI SC36 MLR	DC, IEEE LTSC LOM
Localized metadata standards	Refer other standards
EdNa Online	DC
Gateway to Educational Materials	DC
ARIADNE	IEEE LTSC LOM
UK LOM Core	IEEE LTSC LOM
CELTS-3	IEEE LTSC LOM
Can Core	IEEE LTSC LOM
ADL SCORM	IEEE LTSC LOM
SingCore	IMSLRM

Table 2 Comparisons of LOM-Like Standards

	DC	LOM	MPEG-7	MAWG
Number	Less	Many	Many	General
Content	Less	General	Less	Less
Education	General	Many	Less	Less
Rate	High	Low	General	General
Multimedia	Low	Low	High	General
Interoperability	General	Low	Low	High
Semantic	Low	General	Low	General
Field	Digital library	Learnin objects	Multi-media	Web resource

The first row in Table 2 lists the characteristics we are going to do the comparison among different standards: *Number* is the metadata elements amount. *Content* is how many metadata elements are used to describe the resource's content. *Education* indicates the ability of describing resource's education properties. *Rate* is the average ratio of using each element in the standard. *Multimedia* indicates the ability of describing resource's multimedia properties. *Interoperability* is the interoperating and mapping ability among metadata standards. *Semantic* expresses the semantic ability of metadata elements. And, *Field* is the application domain that the standard mainly used to.

LOM and MPEG-7 have more metadata elements than DC and MAWG. DC is very general and concise. MPEG-7 has more descriptors for technical and low-level characteristics of multimedia. MAWG has necessary elements for mapping among different LOM-like standards. The more elements a standard has may cause elements have lower usage ratio. For example, only few data elements of IEEE LTSC LOM are used in practice [19].

IEEE LTSC LOM has more metadata elements in describing contents and educational attributes than DC, MPEG-7 and MAWG. DC is not good at describing the contents [1]. DC, MPEG-7 and MAWG all miss some elements in describing resource's educational properties. IEEE LTSC LOM is the better choice for education/learning objects.

However, IEEE LTSC LOM lacks elements for the educational needs of multimedia learning objects. From the view points of describing multimedia ability, MPEG-7 is better than DC, IEEE LTSC LOM and MAWG.

The unified meaning of each element is important to interoperability in solving language and culture differences. MAWG has better interoperability than other LOM-like standards. In general, all LOM-like standards have to improve its semantic description ability.

Regarding application domains: DC is mainly used for digital library or digital text-based resource management system; IEEE LTSC LOM is mainly applied in learning/education objects management system; MPEG-7 is widely used in multimedia resource system; and, MAWG will be used for web resource.

3 Implementation Technologies of Metadata

Metadata should be coded into programming languages in order to make computers understand. So the learning objects are sharable and exchangeable on the Internet. eXtensible Markup Language (XML), Resource Description Framework (RDF), Ontology and Semantic Web are important techniques of implementing and interpreting metadata.

3.1 Extensible Markup Language

Extensible Markup Language (XML) is a simplified subset of Standard Generalized Markup Language (SGML). Many resource management systems use XML in sharing and exchanging data on the web. LOM-like standards also use XML to implement metadata applications, such as IEEE LTSC LOM, DC.

There are some XML related specifications: XML Schema, XML Pointer Language (XPointer) and XML Linking Language (XLink), Extensible Style Language (XSL). XML schema is a data model language and can be used to store structured information.

3.2 Resource Description Framework

Resource Description Framework (RDF) is used to describe information of any resource on the web. Resource Description Framework (RDF) is an essential metadata model language [20]. Its syntax can be interoperated and used by independent parties [17-18]. As a part of W3C's Semantic Web Activity, RDF is written in XML to be readable and understandable by computers. Some LOM-like standards use RDF expressing metadata, such as DC.

RDF uses an object-attribute-value triple method to describe resources on the web. For example, "Total solar eclipse" is a learning object. "Creator" is one of the learning object's properties, and "John" is the value of "Creator".

RDF use text to describe properties and values of multimedia on the web. So, RDF can express high-level semantic of text [1][18].

3.3 Ontology

Ontology is an explicit specification of concepts and relations within a domain. Ontology is useful for reasoning and retrieving concept properties.

The common components of ontology include individuals, classes, attributes, relations, function terms, restrictions, rules, axioms, and events. Ontology is a knowledge representation and be used in many application domains. All domains hope to construct a complete and extensible ontology for representing domain specific knowledge and providing diverse services such as searching and acquisition [12]. Semantics of multimedia resources are difficult to recognize by computers automatically, hence, it is necessary to design ontology for multimedia.

Web Ontology Language (OWL) is one of ontology languages for representing web information. OWL is part of the Semantic Web. The classes, properties and individuals of OWL are defined as RDF resources and can be identified by URIs [17][21]. As a W3C standard, OWL is written in XML and similar to RDF. OWL has more vocabularies and stronger syntax than RDF, and has greater interoperability than RDF [17-18].

3.4 Semantic Web

A word may have different meanings in different situations. Machines only take a word as a symbol and don't know the word's semantic meanings in different situations. W3C Semantic web working group defines that semantic web is a web of data which can be shared and reused by different applications, enterprises, and community boundaries. Semantic web is composed by XML, XML Schema, RDF, RDF Schema, OWL and Simple Protocol and RDF Query Language (SPAQL) [18][20].

4 Educational Viewpoints of Multimedia Learning Objects

Multimedia is the integration of two or more content forms including text, image/picture, video, audio, animation and interactive content. Multimedia learning objects can improve learning efficiency [10][21]. Some teaching contents can be clearly expressed only by multimedia learning objects, such as physical and chemical experiments. So, the number of multimedia learning objects grows rapidly.

4.1 Educational Features

Multimedia learning objects have so many features that they are widely used for educational needs [29-31]. Multimedia learning objects have the followings typical educational features compared to single media learning objects:

4.1.1 Enhance the Cognitive Process Ability

Multimedia learning objects present knowledge by vivid explanation. Learners can easily and quickly construct knowledge in multimedia learning objects and integrate prior knowledge stored in their long-term memory. Multimedia learning objects make learners do cognitive activity and constructive learning more actively than single media learning objects [28][32].

4.1.2 Are Good for Lower-Skilled Learners

The multimedia learning objects are more effectively in improving academic performances of lower-skilled learners than higher-skilled learners [10][21-22]. The main reason is that multimedia learning objects can make abstract knowledge become more specific and intuitive than single media learning objects. Multimedia learning objects represent knowledge through several forms, such as text and picture. A lower-skilled learner may not understand the principle of simple pendulum by text. However, the pictures concretely describe the whole process of simple pendulum. The learner can understand the knowledge with the help of pictures.

4.1.3 Attract Learners' Attention

Multimedia learning objects can get learners' attention by multi-sensory stimulation [23-25]. Single media learning objects only stimulate one sensory of learners. Multi-sensory stimulation can make learners have more sensors focus on learn contents than single sensory stimulation. Multimedia learning objects can make learners pay more attention than single media learning objects at the learning beginning.

4.1.4 Improve Interactions

Multimedia learning objects can have interactive facility. For example, Cochrane uses QuickTime to build interactive multimedia learning objects [26].

4.1.5 Provide Personalized Presentation Form

Multimedia learning objects can have different presentation forms for learning contents. Learners can choose their preferred presentation forms. For example, Tom likes learning by watching video without subtitles. He can manipulate the multimedia learning object to satisfy his requirement. Single media learning objects have only one presentation form. Learners can not choose their preferred presentation forms when they access single media learning objects.

4.1.6 Contain Rich Pedagogical Features

Pedagogical features of learning objects are very important, especially for reusable learning objects [27-28]. Pedagogical features include instruction design, instruction method and teaching strategy. Single media learning objects usually present learning contents only. Multimedia learning objects not only present content but also design interaction between students and contents. For example, Susan (teacher) designs a multimedia learning unit to express the dependent variable growth differences between exponential function and logarithmic function. She applies instructional design theory into the multimedia learning objects. She considers knowledge points' sequence, text color and font size. She designs dynamic function graphs to show the growth differences between two functions. The dynamic function graphs support interaction. Students can type different index to see the growth features of exponential function and logarithmic function. So, multimedia learning objects contain more pedagogical features than single media objects.

4.1.7 Decrease Information Overload

Multimedia learning objects can help learners receive information from different channels (e.g., ears and eyes) to decrease occupied capacity of each channel. Single media learning objects make learners receive all information through a single channel and make the channel overload easily.

4.2 Multimedia Learning Object Types

Object types make managers index and archive multimedia learning objects easily, and help teachers and learners search multimedia learning objects efficiently. How to classify multimedia learning objects? It is necessary to understand existing media types and learning objects types.

Media types have been developing with technology. Early in 1995, Heller & Martin classified media types into text, graphics, sound, and motion [32]. In 1999, they took account of context and attribute in multimedia types [33]. Media context includes audience, discipline, interactivity, quality, usefulness, and aesthetics [34]. Aleem (1998) thought multimedia interactivity included text system activity and user activity [35]. Taxonomy of multimedia defined three dimensions which are media type, contextual expression and interactive expression [36]. Contextual expression includes extraneous, relevant and germane. Interactive expression includes passive, reactive, proactive and directive interaction.

Learning objects have several classifying methods. Learning objects are classified into course, partial course, learning unit, and knowledge unit [37]. On the basis of IEEE LTSC LOM, taxonomy for learning objects was provided according to intended end user role, subject, and so on. Learning objects are also classified into teacher-oriented and student-oriented [4]. Moreover, learning objects should be connected with pedagogy which is especially important for reusable learning resources [4] [38]. Machines can search satisfying results for learners/ teachers when pedagogical features of learning objects are described.

Based on the analysis above, we classified multimedia learning object types into three dimensions: media, learning content, and pedagogy (educational features), as Figure 1 shows.

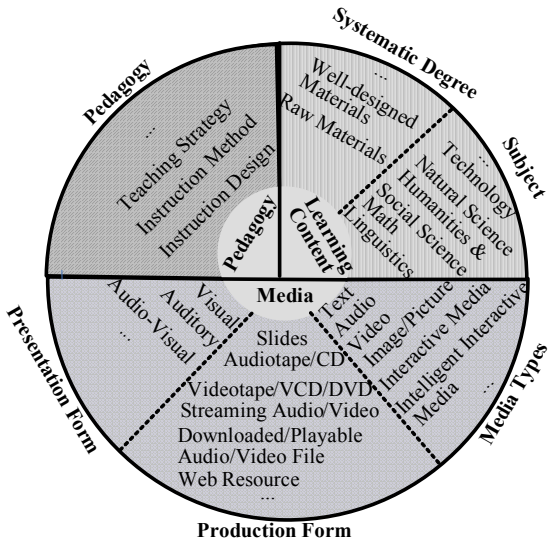


Figure 1 Multimedia Learning Object Types

Media dimension has three sub-dimensions: media type, media presentation form and media production form.

From the media presentation form viewpoint, multimedia learning objects may be audio media, visual media, and audio-visual media. For example, text and image/picture are visual media. Video, animation, interactive media and intelligent interactive media are audio-visual media. Different presentation forms can help learners learn efficiently in different ways [10][21][23-26] [31].

Regarding production forms, multimedia learning objects may be audiotape/CD, videotape/VCD/DVD, slides,

courseware, streaming audio/video, downloaded/playable file (e.g., text, audio, video), web resource(e.g., wiki, blog, dictionary), and so on.

Learning content dimension has two sub-dimensions: subject and systematic degree. The systematic degree shows the functional granularity of a learning object, and the integration degree between material and pedagogy. Regarding subjects, take China's education of grade 1 to 12 for example, subjects may be linguistics (Chinese, English, etc.), math, humanities and social science (moral, politics, history and geography), natural science (chemistry, physics, and biology science), technology (information technology, vocational technology), art (arts, music), physical education and health.

Regarding systematic degrees, the multimedia learning objects may be raw materials and well-designed materials. Raw materials are raw media data or fragments. Raw materials are not altered by teachers or developers. So raw materials generally don't have pedagogical features. Well-designed materials usually have pedagogical features injected by teacher or developers. Knowledge units, learning units, and courses are well-designed materials. Obviously, well-designed materials are more systematic than raw materials.

Pedagogy dimension is very useful to learners/teachers to improve multimedia learning objects' utilization [4] [38]. Usually, pedagogy is related to educational features, for example, instruction method, instruction design, and teaching strategy. Pedagogy dimension can increase the multimedia learning objects' semantic level to help learners/teachers finding/designing personalized learning objects.

A multimedia learning object has three semantic levels: low-level, mid-level and high-level. Low-level semantics is generated by the object's technical features, such as media types, presentation forms and production forms and media formats. Mid-level semantics is mainly constructed by learning content dimension, such as subject, keywords and abstract. High-level semantics is pedagogy dimension that is closely related to educational features and needs.

A multimedia learning object covers multiple object types. Subject, pedagogy and presentation forms are important dimensions to satisfy the needs of teachers and students.

4.3 Differences between Multimedia and Single Media Learning Objects

The differences between multimedia and single media learning objects are: (1) storage capacity, (2) presentation form, (3) entity number, (4) search difficulty, (5) metadata requirement and (6) semantic level expression ability of LOM-like standards and technologies. Multimedia learning objects need more storage capacity than single media objects for the same learning unit. Unlike multimedia, the presentation form of single media is either visual or auditory.

The main differences between multimedia and single media learning objects are its entity number and semantic level express ability. Learning objects have rich semantics if it has many entities. The rich semantics need stronger description ability of metadata elements which cover learning objects' attributes and features. The following paragraphs describe the detailed differences in entities and semantic level description ability of LOM-like standards & technologies.

The entity number of multimedia learning objects is usually more than single media as Table 3 shows. Single media contains only one or two entities but multimedia usually contains two or more.

Entity is perceptible information object. We classify entity into on-screen words, narrative voice, background sound, real and virtual objects, interaction and intelligent interaction.

On-screen words, real objects and virtual objects are visual information. On-screen words usually are text and subtitles. Existing LOM-like standards are widely used for text resource management systems. Technologies of text searching and character recognition are matured and more reliable than audio and video recognition. Table 4 shows the ability that LOM-like standards and technologies can describe the three semantic levels.

Real objects are living and unliving objects. Living objects are animate, such as human, animals, and plants. Unliving objects are inanimate, such as blackboard, desk, and pen. Virtual objects are made by digital technologies. Some inanimate virtual objects may be personified by digital technologies. Animate and personified objects have a high-level of semantics. They have emotions and expressions, and can act and talk.

Narrative voice and background sound are auditory information. Auditory information needs voice recognition technology to generate semantics. Existing LOM-like standards and technologies have similar disadvantages in representing auditory information.

Interaction is hands-on behaviors between users and media objects. Intelligence is media object's ability to adapt to different users' requirements. Interaction and intelligence only exist in multimedia resources.

Table 4 shows the differences of describing semantics for single media and multimedia based on LOM-like standards and technologies. Multimedia usually contains dynamic real and virtual objects. For example, lecture videos record teachers and students' discourse, behaviors and expressions, interactions, and teachers' pedagogies. Multimedia have a higher level of semantics than single

Table 3 Entity Differences between Multimedia and Single Media Learning Objects

Sensory	Entity \ Category	Single Media				Multimedia					
		Text	Image/ Picture	Audio	Text Image/ Picture	Text Audio	Image/ Picture Audio	Video	Animation	Interactive media	Intelligent interactive media
Visual	Subtitles	✓			✓	✓		✓	✓	✓	✓
	Real objects: Living objects		✓		✓		✓	✓		✓	✓
	Unliving objects		✓		✓		✓	✓		✓	✓
	Virtural objects: Living objects		✓				✓		✓	✓	✓
	Unliving objects		✓				✓		✓	✓	✓
Auditory	Narrative voice			✓		✓	✓	✓	✓	✓	✓
	Background sound			✓		✓	✓	✓	✓	✓	✓
Tactile	Interaction									✓	✓
	Intelligence										✓

Note. Symbol "✓" stands "has." For examples, text has on-screen words. Video has subtitles (on-screen words), real objects narrative voice and background sound.

Table 4 Differences of LOM-like Standards & Technologies in Describing Semantic Ability for Single Media and Multimedia Learning Objects

Entity \ Category	Single Media				Multimedia					
	Text	Image/ Picture	Audio	Text Image/ Picture	Text Audio	Image/ Picture Audio	Video	Animation	Interactive media	Intelligent interactive media
Low-level semantic: Technical features (format, size,...)	+	+	+	+	+	+	+	+	+	+
Object nature features (color, shape, texture,...)	+	+	–	+	–	+	0	0	0	0
Mid-level semantic (subject, abstract, keywords,...)	++	0	+	+	+	0	–	–	–	–
Hig-level semantic (pedagogy,...)	++	0	–	0	+	0	–	–	–	–

Note. Symbols which are "++", "+", "0", "-" describes semantic ability of LOM-like standards and technologies to a media. Symbol "++" means LOM-like standards and technologies can better describe semantic information of media. Symbol "+" means LOM-like standards and technologies normally describe semantic information of media. Symbol "0" means LOM-like standards and technologies badly describe semantic information of media. Symbol "-" stands for LOM-like standards and technologies poorly describe semantic information of media.

media. Multimedia resource administration and description on the other hand are more difficult than single media.

LOM-like standards and technologies are more difficult in describing semantics for multimedia than single media as Table 4 shows. Multimedia has more difficulty in searching, sharing and reusing than single media. In general, existing LOM-like standards and technologies are more effectively in describing semantics for single media (especially for text) than multimedia, because

- Text searching and character recognition are matured and more reliable than audio and video recognition.
- Existing LOM-like standards and technologies are better in storing and retrieving semantic descriptions for text rather than multimedia.
- Metadata content structure of existing LOM-like standards is more suitable for single media.
- Metadata implementation technologies have better ability in expressing semantics for single media.

The lack of mid-level and high-level semantics causes troubles in searching, sharing and reusing multimedia learning objects. The automatic mid-level and high-level semantics generation technology is not mature. For example, although image recognition and speech transcription techniques can produce captions for multimedia learning objects, these techniques can not recognize useful pedagogical semantic information from multimedia learning objects.

Metadata is still a solution for multimedia administration and application in education. On the other hand, there is no well-defined multimedia metadata set. It is necessary to analyze metadata design issues for multimedia learning objects. These issues help us construct good metadata content structure and implementation technologies for educational multimedia resources.

5 Educational Multimedia Metadata Design Issues

The existing LOM-like standards have difficulties in dealing with the multimedia learning objects' integration, delivery, exchange and interoperate issues [35]. We introduce the obstacles that users may encounter at different phases of using multimedia learning objects and analyze metadata design issues.

5.1 Metadata Content Structure for Multimedia Learning Objects

IEEE 1484.12.1 standard for LOM defines nine categories as metadata content structure. Some scholars classify metadata content structure into technical metadata, life-cycle metadata, right metadata, content metadata, and context metadata [11-12].

Technical metadata is low-level semantics which is independent of learning contents, such as color, shape, size, format and so on. Technical metadata mainly describe learning objects' technical features. Life-cycle metadata is low-level semantics which is independent of learning contents, such as authors, version and create date. Right metadata is low-level semantics which is independent of learning contents, such as copyright and other restrictions.

Content metadata is mid-level semantics which is dependent of learning contents, such as title, subject, and keywords. Content metadata is important to resource managers classifying and organizing learning objects as well as users searching learning objects. Context metadata is high-level semantics which is dependent of learning contents, such as pedagogy. Context metadata is necessary to provide learners personalized multimedia learning objects.

Different metadata types have different functions for management and utilization purposes. Resource developers, teachers, learners and resource managers can use metadata functions, such as indexing/archiving, retrieving/searching, sharing and reusing, evaluating, and interoperating at the five phases of multimedia learning object life cycle [1-3] as Figure 2 shows.

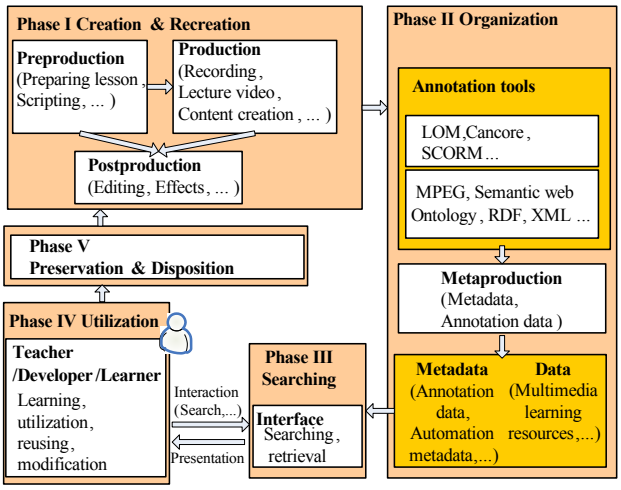


Figure 2 Multimedia Learning Object Life Cycle [1-3]

Metadata elements are identification cards and tags for multimedia learning objects in the life cycle. Without metadata, multimedia learning objects can not be stored and found appropriately. Metadata can enhance application efficiencies of multimedia learning objects.

Taking lecture videos' life cycle for example, resource developer prepares scripts and video recording tools. The camera can automatically generate some metadata element values (Phase I), such as date, time, size and format. These metadata elements however are not enough for storing and managing lecture videos.

The lecture video must be stored in the database and be tagged with essential descriptive information in order to be found easily by other users in the future. Resource manager needs to enter the lecture videos' metadata information further based on LOM-like standards and store the information in database (Phase II).

When users want to search for specific lecture video, they enter some keywords which express what kind of lecture videos they are looking for. The search engine matches the keywords with lecture videos' metadata element values in order to find appropriate lectures videos for the users. The search engine then offers the users the matched lecture video list (Phase III).

Users may review or reuse the videos according to their needs (Phase IV). Some lecture videos stored in database may have never been used. These un-utilized lecture videos will reduce searching efficiency and waste storage space.

Resource manager can use metadata elements to identify and mark the un-utilized lecture videos for management purpose (Phase V).

In the following section, we are going to describe the obstacles users may encounter at different phases of the multimedia learning object's life cycle, as well as the design issues.

5.1.1 Phase I

Phase I is creation and recreation of multimedia learning objects. This phase contains three parts: preproduction, production, and postproduction. For example, Susan (teacher) and John (resource developer) prepare materials, scripts and teaching plans as their first step. At the second step, Susan and John make a lecture video with video recording tools. At the same time, some captured and technical metadata elements are automatically generated by the tool, such as date, time, size and format. At last step, Susan and John add special effects into the lecture video, such as background sound, narrative and subtitles. At this phase, some captured, technical and administrative content and descriptive metadata are created [1-2]. Very few obstacles happen at this phase.

5.1.2 Phase II

Phase II is the organization of multimedia learning objects [2]. A lot of metadata elements mapped to mid-level and high-level semantics must be manually generated for multimedia learning objects. This phase generates metadata by annotation tool based on LOM-like standards and technologies. At beginning, Susan and John can fill out a form which is about multimedia learning objects' metadata information, such as title, author, keywords, date, and so on. Secondly, Susan submits the filled form to Jack (manager). Jack then uses metadata management tools and annotation tools to enter and/or create the metadata information. The metadata information is stored in database.

Meanwhile, Jack also has the opportunity to receive emails from other users regarding the fact that they couldn't reuse the multimedia objects they found for developing their courses. Jack finds that the issue is because the defined metadata content structure is not good enough to describe the multimedia learning objects. Some semantic information of multimedia learning objects is missing, such as teachers' teaching skills, teachers' behaviors and students' behaviors. If he wants to add the missing semantic information, he needs to do a lot of extra efforts.

The issues in this phase should be considered are: (1) What metadata element(s) should be defined for archiving? (2) What metadata element(s) is(are) absolutely critical for efficiently personalized searching and retrieving? (3) What metadata is useful for computers/machines interact with users intelligently? (4) How to classify multimedia learning objects?

5.1.3 Phase III

Phase III is searching. Susan wants to find a multimedia learning object and reuse it for her course. She hopes to search multimedia learning objects from the perspective of pedagogy, presentation forms and systematic degrees. Susan is preparing to teach contents about "total solar eclipse." She wants to find an image or video that shows the phenomenon "oftotal solar eclipse." She also wants to find a lecture video which contains good pedagogy in teaching "total solar eclipse." She also wants to find a lecture video that contains good pedagogy in teaching "total solar eclipse." She is frustrated when she got so many results from search engines. She does not know which one meets her needs and thinks the search results are useless. She is tired of playing videos by scratching or dragging the scroll-bar to find suitable video clip in a random way, which consumes lots of her time. Tom (learner) also wants to find a video about "total solar eclipse" to prepare for his lessons in advance. The video must have narration, he thought. When he searches, he encounters similar obstacles as Susan.

So, at this phase, the main issue is how to search and retrieve multimedia learning objects efficiently?

5.1.4 Phase IV

Phase IV is utilization. Copyright metadata is necessary when users reuse multimedia learning objects. Multimedia learning objects may be utilized, reproduced and/or modified by learners, teachers or resource developers, such as Tom, Susan and John. Susan and John may find some multimedia learning objects can not be reused because its copyright restrictions don't allow other users to use it. On the other hand, sometimes it is caused by softwares and platforms that don't support users revising the objects. Sometimes there are other factors blocking users from reusing and revising. In addition to the utilization issues, the portrait and privacy rights of the multimedia should also be taken into considerations.

The issues in this phase should be considered are: (1) Which metadata can support multimedia learning objects exchanging, sharing and reusing? (2) Which metadata is useful in satisfying users' needs? For example, metadata can describe that pedagogy satisfies Susan's and Tom's needs. (3) Which metadata are useful to enhance utilization efficiency? (4) Which metadata can solve copyright problems of utilization? (5) How to define metadata element(s) to protect the portrait and privacy right?

5.1.5 Phase V

Phase V is preservation and disposition. In this phase, some multimedia learning objects that can not be used or barely used are disposed, and some multimedia learning objects that are useful and may be reused often are preserved. Jack finds that the current content management

system lacks preservation and disposition information for multimedia learning objects. He thinks it is necessary to have metadata to describe multimedia learning objects' preservation and disposition information.

The main issue in this phase is to have metadata elements to describe multimedia learning objects' preservation and disposition information.

According to the obstacles we described above that users may encounter at each phase of the multimedia learning object life cycle, we summarize the key design issues into five categories as Table 5 lists.

The first design issue category is about content, context and technical metadata that support indexing, searching, classification and retrieval of multimedia learning objects. The design issues in this category mainly occur during Phase II, Phase III and Phase IV of the multimedia learning object life cycle.

The second category is about technical, content and context metadata that support sharing, exchange and reusing of multimedia learning objects. The design issues in this category mainly occur during Phase III and Phase IV of the multimedia learning object life cycle.

The third category is about copyright metadata that protects the copyrights of multimedia learning objects. The design issues in this category mainly occur during Phase IV and Phase V of the multimedia learning object life cycle.

Table 5 Metadata Content Structure Issues

Category	Functions	Metadata content structure issues	Metadata types	Life cycle phase
1	Archiving and Indexing	1. Which metadata should be defined for archiving?	Content metadata,	Phase II
	Classifying	2. How to classify multimedia learning objects?	Context metadata	Phase II
	Searching and Retrieving	3. Which metadata is absolutely critical for personalized searching and retrieving based on educational viewpoints?	Content metadata, Context metadata	Phase II Phase IV
		4. How to search and retrieve multimedia learning objects?	Technical metadada, Context metadada	Phase II
	Interacting	5. Which metadata is useful to computers/machines interact with users intelligently?	Content metadada, Context metadata	Phase II
2	Sharing, Exchanging and Reusing	6. Which metadata can support multimedia learning objects exchanging, sharing and reusing?	Technical metadata, Context metadata, Context metadata	Phase IV
	Interoperating	7. How to define some technical metadata to realize interoperation between different platforms and devices?	Technical metadata	Phase III Phase IV
	Utilizing	8. Which metadata are useful to enhance utilization efficiency?	Technical metadata, Context metadata, Context metadata	Phase IV
3	Copyright	9. Which metadata can solve copyright problems of utilization?	Right metadata	Phase IV
		10. How to define some metadata to protect the portrait and privacy right?	Right metadata	Phase IV Phase V
4	Life cycel	11. Which metadata have records about of reproduced and modified information?	Life-cycle metadata	Phase IV
		12. Which metadata can describe multimedia learning objects' preservation and disposition information?	Life-cycle metadata	Phase IV
Other related issues				
5	Optimizing Metadata	13. How to decide the weight of metadata elements to select mandatory elements?		
		14. How to make metadata content structure support expansion? And this structure cannot be restricted by culture difference?		
		15. How to reference and integrate LOM-like standards for multimedia learning objects?		
		16. How to decide which metadata elements are essential [14]?		

The fourth category is about life cycle metadata that records reproduction or modification information. The design issues in this category mainly occur during Phase IV and Phase V of the multimedia learning object life cycle.

The fifth category is related with metadata content structure optimization/evolution that doesn't belong to any phase of the life cycle. For example, how to decide which metadata element(s) is(are) optional, extended and essential?

5.2 Metadata Implementation Technologies of Multimedia Learning Objects

The metadata implementation technologies are used for metadata generation, coding and mapping. The major metadata implementation technologies include XML, RDF, MPEG-7 and Ontology.

RDF uses XML schema definition language describe multimedia learning object metadata so that computers have ability to identify the contents and to know the semantics of multimedia learning objects. MPEG-7 is used to store technical and low-level semantic metadata of multimedia. Ontology constructs domain concepts and the concept relations, is useful to users doing efficiently searching and to computers doing reasoning.

Managers and users always encounter the following obstacles when they manage and (re-)use the multimedia learning objects: (1) existing metadata implementation technologies have some difficulties in automatically getting metadata which covers high-level semantics of multimedia learning objects; (2) existing metadata implementation technologies have some difficulties in describing and reasoning the relations between learning objects' educational features; and, (3) LOM-like standards are seldom mapped between different application domains for interoperating.

Pereira, Vetro, and Sikora analyzed multimedia metadata's needs and challenges as follows: ease of use, transparency, application context, and annotation tool [11]. Beside their consideration, we think the implementation technologies should have four more design issues: (1) Describing High-Level Semantic. How to integrate implementation technologies, including semantic web, RDF, ontology, XML and MPEG standard, to get high-level semantic of multimedia learning objects? (2) Metadata Mapping. How to realize the mapping between multimedia learning object metadata and other existing LOM-like standards? (3) Multimedia Learning Objects' Exchanging and Reorganizing. How to use the implementation technologies to exchange and reorganize the multimedia learning objects? (4) Metadata Annotating and Generating. How to design and develop annotation tools and metadata generation tools for multimedia learning objects?

6 Conclusions

Educational multimedia metadata plays an important role in sharable and reusable multimedia learning objects. According to the educational needs and features, this paper first describes the multimedia learning object types and differences between single media and multimedia. The differences show that the existing LOM-like standards have difficulty in describing mid-level and high-level semantics of multimedia learning objects. The existing LOM-like standards have to add some context metadata for multimedia learning objects, especially in educational features and needs, such as pedagogy. From educational point of view, the metadata implementation technologies also need to be improved in describing high-level semantic, doing metadata mapping, exchanging and reorganizing multimedia learning objects, and designing annotation tools.

Now we know the design issues of the metadata and implementation technologies for multimedia learning objects, our next task is to define metadata content structure based on the educational viewpoints and requirements. We will investigate the requirements and obstacles which the teachers, developer, learners, managers and other educators have considered and encountered. We will know (1) which metadata fields are mandatory, optional and expansible; (2) which metadata fields should be added in order to satisfy the educational features and needs; (3) what are the users' educational searching habits and characteristics; (4) which metadata fields should be revised and/or added to improve searching efficiency; and, (5) what is the best annotation tool.

Once we got all above questions answered, we will be able to design and develop the annotation tool. The tool helps users manually annotate the metadata that covers high-level semantics of multimedia learning objects.

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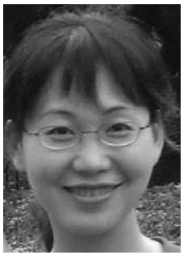
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