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Implications and Challenges of Educational Standards Metadata

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Public elementary and secondary school teachers are now teaching a standards-based curriculum using state or district standards to direct their teaching. Standards-based education has implications for the way teachers are searching for information in libraries. Ideally teachers should be able to use educational standards in their searches to find relevant resources for use in their classrooms. So-called standards-based searching cannot take place without educational standards information in the resource metadata, which brings about interesting issues and challenges.

KEYWORDS educational standards, educational metadata, educational standards metadata, standards-based search, standards assignment

STANDARDS-BASED EDUCATION

Educational standards metadata needs to be added to resources to increase findability of instructional materials for standards-based teaching. Several challenges preclude the widespread creation and use of this particular type of metadata. This paper discusses standards in education, cataloging standards as metadata and their appearance in metadata records, and the issues and challenges related to standards as metadata.

The 1983 report "A Nation at Risk" by the Commission on Excellence in Education is generally seen as the impetus for the creation of educational standards (Kendall, 2003; Purpose of this Work, 2009; Sutton, 2008). The report expressed concern about U.S. students not being able to compete with the rest of the world due to the lack of quality education. One of the suggested approaches for resolving the perceived crisis in education was the

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creation of measurable standards (National Commission on Excellence in Education, 1983). The National Council for Teachers of Mathematics was the first group to create a set of standards—in the area of mathematics—and other organizations quickly followed suit. These national-level standards aimed to clearly define what students in certain grade levels are expected to know in core subject areas (Ratvitch, 1995). Eventually all states published their own educational standards, often using the national standards as a guideline.

Educational standards describe what students should know in what grade about a particular subject and what skills they are supposed to demonstrate in relation to this knowledge. Standards ensure that, rather than creating separate disjointed educational units, a larger plan for learning is formed with units that are connected and presented to students in a logical order. Thus, standards can guide the curriculum and assessment and also inform teacher education itself (Nelson, 1997). Standards typically contain general statements of what students should know and be able to do, followed by specific expectations, also referred to as indicators or benchmarks (Reeves, 2004). An example of a geometry standard for the state of Massachusetts can be found in Figure 1. We use the term educational standard to mean the general statement and the more specific expectation. The literature refers to educational standards as achievement standards, learning standards, academic standards, content standards, skill standards, competency standards, benchmarks, and performance standards (Sutton, 2008; Sutton & Golder, 2008).

Standards still play an important role in education today. Most recently, the No Child Left Behind Act of 2001 stipulated that states develop standards in core subject areas and hold schools responsible in case their students

Students engage in problem solving, communicating, reasoning, connecting, and representing as they:

K.G.1 Name, describe, sort, and draw simple two-dimensional shapes. :

K.G.2 Describe attributes of two-dimensional shapes, e.g., number of sides, number of corners.:

K.G.3 Name and compare three-dimensional shapes. :

K.G.4 Identify positions of objects in space, and use appropriate language (e.g., beside, inside, next to, close to, above, below, apart) to describe and compare their relative positions.

FIGURE 1 State standard example: Massachusetts Math (Geometry; Grades PreK–6).

do not measure up against these standards. This provision is known as the Standards-Based Accountability provision and the provision heightened efforts in the creation of standards as well as standards-based content.

Curricular resources ranging from lesson plans to computer simulations bring teachers and their students to the competencies represented by educational standards. A growing number of the educational resources in online collections (National Science Digital Library; Thinkfinity.org; TeachEngineering.org) now have national and state educational standards added to their metadata records which describe the resource. Commercial content provider ProQuest now offers standards-based searching in several of their databases (Taylor, 2004). This means that educators could potentially search these online repositories by using the standard that corresponds to what they are teaching (e.g., *Students will understand that the appearance of the moon changes in a predictable cycle as it orbits Earth and as Earth rotates on its axis*) to find relevant materials to use in their classrooms (Diekema & Chen, 2005; Diekema, Yilmazel, Bailey, Harwell, & Liddy, 2007). The retrieved materials (e.g., lesson plans, videos, podcasts) will aid in teaching precisely those concepts described in the educational standard that was used to retrieve the item. Contrary to the importance of this topic, a literature search in the area of educational standards as metadata yielded limited results.

EDUCATIONAL STANDARDS AS METADATA

Digital libraries, such as TeachEngineering.org, contain a wide selection of resources that can help bring teachers and their students to the competencies represented by educational content standards. These educational resources need to be indexed by national and state standards to make them accessible for teachers who are increasingly required to teach to certain educational standards. Ideally, a teacher who is teaching to a particular standard specific to his or her state, subject area, and grade level should be able to find whether there are any lesson plans or other educational materials available that can be applied to the particular class. Before this type of retrieval can take place, educational standard metadata needs to be assigned to resources.

Adding state standard information as metadata for every state to each resource is a large task, especially when done completely manually. Standards assignment is extremely time consuming and a large cognitive burden on the cataloger as standards exist in all core subject areas, on national, state, and local (district) levels. Each set of standards utilizes discrete language, differing grade bands, distinct organizational structures, and different levels of specificity in the coverage of a particular standard. On top of this, numerous sets of standards can apply to a single educational resource and alignments must take into account the various levels in the hierarchical organization of educational standards.

Most approaches to the daunting task of adding educational standards as metadata range from ignoring standards altogether to adding standards at the national level only. The problem with both approaches is that they are not satisfying the information-search needs of teachers. A focus group held by Devaul and Kelly (2003) confirms what teachers have told us informally over the years, which is that they want to search using the standards they are using in their teaching. Figuring out which national standard closely represents their own standard and using the national standard to search a library is too cumbersome and defeats the purpose of a standards-based search: using the standards that you are teaching in the classroom to find relevant resources to use in your teaching (Kendall, 2003). To provide useful and functional standards-based search capabilities, educational standards need to be added to metadata records at least at the state level. What is the best way to go about this task in a timely and affordable manner?

EDUCATIONAL STANDARDS CATALOGING TOOLS

Adding educational standards from every state to the metadata record of every educational resource in a library can be done manually by subject-matter experts, fully automatically by machine, or by a computer-assisted approach by which the human and machine efforts are combined.[1] In some cases content creators as well as content users are encouraged to add educational standards to the material they create or use. Aside from consistency and quality control issues, this Web2.0 solution is limited with regard to coverage because the assigned standards are usually limited to the user's home state plus perhaps a national standard.

There are several companies, such as Academic Benchmarks (n.d.) and EdGate (n.d.), that provide so-called standards assignment services to customers. There has been some criticism in the literature however about using proprietary educational standards databases that might hinder interoperability (Sutton, 2008) or, worse, render cataloging useless in case these companies should go out of business.

An alternative to the proprietary standards databases is the Achievement Standards Network (ASN), which is a national repository of machine-readable educational standards represented in the Resource Description Framework (RDF) language (Sutton & Golder, 2008). The RDF representation means that each standard and indicator within a standard in the ASN has a unique identifier (URI) that can be referenced online. This makes it easy to use by standards cataloging software and facilitates sharing of standards information between systems. An example of a standards cataloging system that uses the ASN standards is the Content Assignment Tool (CAT) developed at Syracuse University through funding by the National Science Foundation. CAT follows a computer-assisted approach where a machine does the initial leg work

by using natural language processing and machine-learning techniques to present a list of likely standard candidates to the cataloger based on the resource to which he or she is trying to assign standards.

CAT assists collection providers, catalogers, and teachers in assigning educational standards by providing suggestions of relevant standards. The Tool makes suggestions that are reviewed by the individual adding the resource to a library collection. The user then selects and approves the final assignment. Also, if the individual adding the resource would like to consider other standards, the system allows the user to browse a hierarchical list of available standards and select and add their preferred standards to the list of suggested standards. The system stores these human-vetted assignments and utilizes machine-learning techniques in order to improve its own auto-suggestions. This learning can take place at the single-cataloger level or at the organizational level where all assignments from multiple catalogers in an organization are aggregated.

CAT currently provides 30% to 50% of the standards a human would assign (Devaul and Ostwald, 2007) which substantially reduces search time necessary to identify standards in large, complex standards lists and greatly speeds up the cataloging process. Clearly, a human needs to remain in the loop to select the correct standards from among the list of suggestions, as well as to possibly select additional standards that might have been missed by the system. Assigning educational standards to resource metadata automatically, which is what CAT does, remains quite challenging as there are many issues yet unresolved.

CHALLENGES AND ISSUES IN SEMI-AUTOMATIC STANDARDS ASSIGNMENT

Nearly all of the challenges facing automatic standards assignment are caused by language or vocabulary issues inherent in standards and educational resources. The other major issue is related to the way some standards are written that necessitates a process of *unwrapping* (explained later) before determining to what extent a standard correlates with an educational resource (Kendall, 2003).

The main challenge in trying to correlate standards with resources automatically is the vocabulary gap between standards and educational resources. Standard indicators tend to be short, high-level abstract statements about what a student should be able to do or understand, whereas educational resources are practical applications of these theoretical constructs that require different vocabulary to be explained. This difference in conceptual level impedes the system when trying to find commonalities between the standard and the resource.

In some extreme cases there is no overlap between the vocabulary used in the educational resource and the vocabulary from the standard that should be assigned to the lesson plan. Situations such as these require a conceptual match rather than a straight vocabulary match, which is difficult for computer-based systems (Diekema & Chen, 2005). For example, a standard about the use of fractions might not be picked up by the system as appropriate for a lesson plan describing an activity with paper plates and scissors where the students first cut plates in half, then a half in half to get a quarter of a plate and so on.

Conversely, there are situations where the educational resource and a standard do share key vocabulary, and the automated system assigns that standard inappropriately because the system missed key terminology that was not shared. For example, a resource on number operations in mathematics that lists the operations with which students should be familiar before attempting a new operation, such as division, might be erroneously correlated with a standard on addition and subtraction.

Besides the vocabulary challenges, there is an additional issue that makes it difficult for automated systems to determine which standards would be suitable as metadata for a certain resource and that is the granularity issue identified by Kendall (2003) and also mentioned by Sutton (2008). The problem is that standards sometimes have a number of finer-grained concepts contained within them. Sutton illustrates this problem with the following Ohio standard: "Analyze and solve multi-step problems involving addition, subtraction, multiplication and division using an organized approach, and verify and interpret results with respect to the original problem." This standard has many different concepts represented within it and requires a process called unwrapping to carefully separate out all these concepts and skills (Ainsworth, 2003). The Ohio standard, when unwrapped, describes 16 different concepts. A system would need to take all 16 concepts into consideration to determine whether the standard correlates to a particular resource.

The granularity issue has important implications for how the correlation between standard and resource is represented in the metadata record. It appears pertinent, at a minimum to indicate the strength of a correlation and, ideally, exactly what concepts constituted the correlation.

EDUCATIONAL STANDARDS IN THE METADATA RECORD

The main purpose of adding educational standards to metadata is to facilitate standards-based searching, which is very important now that teaching is becoming increasingly standards based. To ensure accurate (high precision) standards-based searching, metadata needs to be assigned with the utmost care, and information needs to be provided about the strength of the

correlation (strength of fit). Strength of fit information can be taken into account by the retrieval systems in ranking the results. Ideally, the standards are unwrapped so that the system can provide exact information about which concepts within the standard are represented in the resource. When teaching about stationary objects and Newton's first law, a lesson plan on moving objects is not going to be as relevant. A lesson treating both stationary and moving objects might have a strong correlation to the standard *Use Newton's first law to explain the motion of an object,* while the stationary object lesson might have a weaker correlation to indicate that additional materials might be needed to cover the entire standard.

When we examine how standards might be represented in the more prominent cataloging and metadata frameworks such as MARC, Dublin Core, Learning Object Metadata (LOM), and Gateway to Educational Materials (GEM), it becomes clear that the representation of standards in metadata has a lot of room for improvement.

Educational standards can be represented in the MARC cataloging record in the curriculum objective field (658) and its subfields (Library of Congress, 2008) (see Figure 2). The standard itself (e.g., *Students will expand number sense to include operations with rational numbers.*) is listed in subfield a and the standard indicator (*Model and illustrate meanings of operations and describe how they relate.*) can be listed in subfield b. The standard identifier or code can be listed in subfield c, if applicable. The correlation factor or

658	##$aReading objective 1 (fictional)$bunderstanding language, elements of plots, themes, motives, characters, setting by responding to the multiple-meaning word$cNRPO2-1991$dhighly correlated.$2ohco
658	##$aMath manipulatives$dhighly correlated.$2[source code]
658	##$aDrug abuse awareness$bpeer pressure$bunderstanding the law.$2local
658	##$aHealth objective 1$bhandicapped awareness$cNHP01-1991$dhighly correlated.$2ohco
658	##$aReading objective 1$bidentify, locate, and use information$cNRP01-1991.$2accssd
658	##$aHealth objective 1$bhandicapped awareness$cNHP01-1991$dhighly correlated.$2ohcoHealth objective 1: handicapped awareness [NHP01-1991]-highly correlated.

FIGURE 2 Educational standards in MARC field 658.[2]

```
<nsdl_dc:nsdl_dc schemaVersion="1.02.010"
xmlns:nsdl_dc="http://ns.nsdl.org/nsdl_dc_v1.02/" xmlns:dct="http://purl.org/dc/terms/"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://ns.nsdl.org/nsdl_dc_v1.02/
http://ns.nsdl.org/schemas/nsdl_dc/nsdl_dc_v1.02.xsd">
    <dct:conformsTo xsi:type="dct:URI">http://purl.org/ASF/LearningStandardDoc/2E4EC33B-
    AAC0-4A84-9580-C7994463C877</dct:conformsTo>
    <dct:conformsTo
    xsi:type="dct:URI">http://url.for.an.edStandard/withoutAnASN/identifier</dct:conformsTo>
    <dct:conformsTo>Rhode Island Second Grade Science Standard RI86.2</dct:conformsTo>
</nsdl_dc:nsdl_dc>
```

FIGURE 3 Educational standards in the NSDL Dublin Core.[3]

strength of fit goes in subfield d (slightly correlated, moderately correlated, and highly correlated). Finally subfield 2 lists where the standard terminology originated.

The Education Working Group within the Dublin Core Metadata Initiative (DCMI) proposed several ways to record standards information in the metadata schema but only the *conforms to* field is currently in use—with a status of "recommended" (see Figure 3). There are no clear guidelines on what information can go into that field, as evidenced by the NSDL DC metadata, in which the field contains text (presumably of a standard) or a URL (most likely a pointer to a standard in the ASN database). Another problem with this metadata field is that there is no way to indicate the strength of the correlation (DCMI Home: Dublin Core Metadata Initiative [DCMI], n.d.).

The IEEE's LOM *classification* category is used to record information about, among other things, educational objective or competency. Here catalogers can document the relationship of the learning object to any classification scheme (see Figure 4). There is no clear directive about including educational standards, and there is no official way to indicate the strength of the correlation (IEEE, 2005).

GEM extends the Dublin Core Descriptive Metadata for education resources by adding specific GEM elements to the metadata framework, and it has an element called *standards* to record state and national standards pertaining to a resource (see Figure 5). In the element's documentation GEM recommends catalogers to record information about the standards body that issued the standard, the domain of the standard (e.g., Science), the version

```
<classification>
<purpose>
<source>LOMv1.0</source>
<value>educational objective</value>
</purpose>
<taxonpath>
<source><string language="eng">Alberta Learning Outcomes 2</string></source>
<taxon><entry><string language="eng">Science</string></entry></taxon>
<taxon><entry><string language="eng">Grade 12</string></entry></taxon>
<taxon><entry><string language="eng">Physics 30</string></entry></taxon>
<taxon><entry><string language="eng">Electric Forces and
Fields</string></entry></taxon>
<taxon><entry><string language="eng">Major Concept - Coulomb's law relates electric
charge to electric force</string></entry></taxon>
<taxon><entry><string language="eng">Knowledge - Students should be able to
demonstrate an understanding that: Coulomb's law explains the relationships among force,
charge and separating distance by explaining, quantitatively, using Coulomb's law and
vectors, the electrostatic interaction between discrete point
charges</string></entry></taxon>
</taxonpath>
</classification>
```

FIGURE 4 Educational standards in IEEE's LOM.[4]

of the standard, the grade levels of the standard, the text of the standards, and who established the correlation between the resource and the standard. Note that the correlation strength is not recorded in the metadata (Standards, 2004).

Judging by the varying ways of registering standards information and differences in prominence of the standards within metadata schema, there appears to be a lack of agreement about how to handle educational-standards information. This is very unfortunate as it will affect how well teachers can expect to find relevant resources using a standards-based search mechanism.

```
<!-- Begin: Standards Declaration -->
- <rdf:Property rdf:about="http://purl.org/gem/elements/standard">
    <rdfs:label>Standards</rdfs:label>
  - <rdfs:comment>
      State and/or national academic standards mapped to the entity being described.
    </rdfs:comment>
    <rdfs:isDefinedBy rdf:resource="http://purl.org/gem/elements/"/>
  </rdf:Property>
<!-- End: Standards -->
```

FIGURE 5 Standards declaration in the GEM RDF/XML schema.[5]

RECOMMENDATIONS FOR EDUCATIONAL-STANDARDS METADATA

When recording standards in metadata records, there are three types of information that need to be recorded: (1) standard content, (2) information about the standard, and (3) information about the correlation between the standard and the resource (see Table 1). The content of a standard can be represented by the text of the standard and indicator itself. Information about the standard should allow the reader to identify who created the standard, what year it was published, what version of the standard was used, what grade level(s) it concerns, and how to identify the standard in case it has an ASN URI or a specific code given by the author of the standard. Correlation information should provide evidence of strength of fit and/or an indication of which concepts from the standard best represent the resource.

While standard content and standard description are straightforward categories, correlation information that records the correlation factor or strength of fit is potentially problematic. Using the MARC correlation strength terminology (slightly correlated, moderately correlated, and highly correlated), for example, does not express what a moderate correlation signifies. Does the resource treat more concepts than listed in the standard or does the standard list more concepts than are represented in the resource? Which concepts from the standard are correlated and which ones are not?

Kendall (2003) suggests utilizing the standards compendium of standards and benchmarks developed by his organization (McREL, n.d.) to tease out the different concepts that are represented in the different standards (Kendall & Marzano, 2000). The compendium is based on an analysis of a set

TABLE 1 Educational Standards Metadata Information

Educational standard facets	Specific standards information	Example
Standard content	Text of the standard	Students engage in problem solving, communicating, reasoning, connecting, and representing as they: Name, describe, sort, and draw simple two-dimensional shapes.
Standard description	Standard URI	http://purl.org/ASN/Resources/S13829jy54300
	Standard code	K.G.1
	Author or standards body	Massachusetts
	Domain	Math
	Year of publication	2000
	Version	Version 1
	Grade level or grade band	PreK–6
Correlation information	Correlator	Unknown
	Correlation approach	Hybrid
	Strength of fit	Partial
	Correlated concepts	Drawing two-dimensional shapes

of standards created by subject-area organizations and additional standards. It distills key standards, topics, benchmarks, and statements of knowledge in 15 different areas. By clearly identifying which of the most fine-grained units of the standard (statements of knowledge) correlate with the resource, the correlation is made completely explicit. Given the labor intensity of this approach, it is unlikely that this solution will find general acceptance unless McREL provides the correlation between the state standards and the compendium. Until this happens we need to find a useful way to express strength of fit.

CONCLUSIONS AND FUTURE RESEARCH

Now that standards-based education is becoming ubiquitous, standards-based searching needs to be created to support information seeking by teachers. Educational standards need to be added to resource metadata records to facilitate this type of searching. Unfortunately, there is currently no agreement on how best to represent educational standards as metadata. There are three types of information that need to be recorded in the metadata: standard contents, information about the standard itself, and information about the correlation between the standard and the resource. Information about the strength of fit or correlation factor is highly complex and will require additional study with regard to the feasibility of different approaches. Given

the increasing demand and importance of standards-based searching, the metadata issues need to be resolved as soon as possible.

NOTES

1. Some approaches to standards assignment do not require an alignment to every state standard. Rather they utilize a so-called crosswalk approach, by which every state standard is aligned ahead of time to the crosswalk or exchange standard so that the resource only has to be aligned to the exchange standard in order to be correlated to all state standards.
2. http://www.loc.gov/marc/bibliographic/concise/bd658.html
3. http://wiki.nsdl.org/index.php/Community:Collections_and_Metadata/EducationalMetadata#Educational_Standards_Alignments
4. http://www.cancore.ca/guidelines/CanCore_Guidelines_Classification_2.0.pdf
5. http://balas.jesandco.org/schema/2002/08/15/gem#

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