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Digitizing Curricula: An Approach for Digital Usability

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Abstract: Steering documents for school, i.e. curricula, syllabi, subject plans and the Education Act, are not generally available in a digitally usable format. That complicates, for example, the process of building advanced curriculum-based services for schools in which individual elements are traceable. To address this problem, Swedish subject syllabi incorporating knowledge requirements for compulsory school were analyzed in terms of their structure, content type and relationship to the subject, year, and grade level. Markup describing the documents was added using Semantic Web technologies such as RDF and Linked Data to make the documents digitally usable. This paper presents a method for analyzing and marking up national steering documents. Digitally usable steering documents open up for services in which digital learning resources are connected to specific parts of the steering documents or in which steering documents from various countries can be compared, for example concerning PISA results.

1. Introduction

Swedish national steering documents (NSDs) for schools, such as the Education Act, curricula, syllabi, and subject plans, are not currently available in a digitally usable format, meaning that they are not part of the emerging digital information ecology of school. Digital information directly connected to specific parts of NSDs is lacking; instead such information is connected to subjects, education levels, and/or entire syllabi. In the worst case digital information is without apparent connections to NSDs, as in the case of material from textbook publishers. This absence of NSDs in a digitally usable format complicates the search for digital learning materials based on NSDs as well as the comparing and matching of information, such as various subject syllabi. In addition, because they are unavailable in a digitally usable format, it is impossible to link data to individual elements of NSDs, such as specific knowledge requirements.

A quality review of upper secondary apprenticeship education [24] identified a need to clarify the connection of workplace-based learning to NSDs. In some cases, there were ambiguities in what was assessed or the workplace-based learning had little impact on the grades. If NSDs were available in a digitally usable format, it would be possible to connect work activities performed in the context of workplace-based learning to various parts of the documents. This would not only document what the students have performed but would make it possible to follow their learning progress in relation to NSDs. The availability of NSDs in a digitally usable format would also make it possible for digital services to present various types of information, such as descriptions of work activities and digital learning resources, in which the common denominator is their relationships and connections to NSDs.

Swedish NSDs for different school forms are similar in their structure and composition. The study presented in this paper focuses on subject syllabi incorporating knowledge requirements for Swedish compulsory school. The Swedish Government has set national goals and guidelines for education through the Education Act and curricula, which include syllabi and subject plans, while the National Agency for Education provides knowledge requirements for the syllabi and subject plans [22, 23]. These documents are collectively called the NSDs for Swedish schools. The Swedish school system is a goal-oriented system in which the subject syllabi for compulsory school consist of an introductory text, aims and core content. Knowledge requirements are specified according to the various grade levels for each subject. The introductory text consists of a short justification of that subject's presence in school, followed by the aims for the subject and ending with a number of long-term goals expressed as subject-specific abilities. In the section specifying the core content of the subject, the text is divided by year ranges (i.e. 1–3, 4–6 and 7–9) and these passages are divided into knowledge area descriptions specifying the minimum content to be taught. The knowledge requirements specify the minimum acceptable knowledge level of a student in year 3 as well as the knowledge level required for grades A, B, C, D, and E in years 6 and 9. The syllabi and knowledge requirements are written in running text, except for the long-term goals at the end of the aims and the core content, which are in bullet points. Swedish NSDs are available as paperback books and in unstructured, proprietary digital formats such as PDF files and Word documents.

How can NSDs for school be made not only digitally available but also digitally usable? Today, there is great demand for digital educational services and ICT is developing rapidly. Schools are embracing new technology and teachers and students are making increasing use of digital tools and services. NSDs are central to schoolwork and, as the use of digital tools and services is increasing, digitally available and usable NSDs may increase the quality of existing services and enable new services to be developed. The study reported here accordingly presents a method for analyzing and marking up NSDs to make them digitally usable. The study should be placed in a wider context of developing the digital information ecology of school by providing services that facilitate the use of digital learning resources.

The first section of this paper provides the background to the research presented. Section 2 gives an overview of previous related projects while section 3 introduces technologies relevant to the study. Section 4 presents the method for analyzing and marking up the NSDs. Section 5 presents the results and section 6 the discussion and conclusions.

2. Previous Related Projects

In the last decade, various international and national projects have been initiated in attempts to connect NSDs and other digital information, such as digital learning resources.

In January 2003 the Department of Education and Skills in the UK launched the Curriculum Online website to allow teachers to search for educational multimedia resources [13]. The project created vocabularies originating from the curriculum, including for example subject, topic, school year and teaching term. Vocabularies can be defined as collections of available terms used in particular areas that also explain how these terms relate to other terms. The content providers created Extensible Markup Language (XML) metadata records describing their learning resources by connecting them to appropriate entries in the vocabularies according to a metadata scheme that enabled searching by, for example subject and school year. For the purpose of this paper, metadata is defined as "machine-understandable data about data". In Curriculum Online, steering documents formed the basis of the vocabularies used to describe learning resources, though there were no direct connections to these documents. The Curriculum Online metadata scheme was an application profile of IEEE-LOM [14], a metadata standard for describing learning objects.

In the Swedish National Curricula Markup (NCM) project, three Swedish NSDs were provided with information structure and metadata markup [17]. The metadata markup consisted of central concepts added to single words that matched the concepts as well as structural markup. Two prototypes were compared, the first using TEI as the markup language and the second using DocBook together with Annotea. By using Annotea in the second prototype, annotations in the form of Resource Description Framework (RDF) [15] statements were pointed into the NSDs using XPointer [10]. XPointer is a framework that makes it possible to point into a specific part of a document. The authors advocated a solution like that of the second prototype that allows various actors "to provide metadata independent of each other and without interfering with the resource or existing metadata" (p. 1736) [17]. In the NCM project, an XML-based format was used as a basis for the NSDs and it was important that adding markup not interfere with this original file or with existing metadata. The study of NCM moreover concluded that it was necessary to separate different types of metadata [15].

The Achievement Standards Network (ASN) has used a similar approach but with a different focus from that described below. It is a repository of US machine-readable and machine-processable achievement standards modeled in RDF [21] that "provides an RDF-based framework for the description of achievement standards promulgated by governments and other organizations [hereafter, "promulgators"] to prescribe what K-12 students should know and be able to do as a result of specific educational experiences" (pp. 189–190) [9]. ASN uses two types of entities, i.e. standard documents and statements. A standard document is fragmented into statements and represented as RDF/XML [2]. Statements from one state standard can be matched and compared with statements from a different state standard. The standard documents contain only one type of statements, i.e. learning objectives, and thereby differ from the Swedish syllabi that comprise introduction, aims, core content, and knowledge requirements.

3. Enabling Technologies

The conventional Web is often called a "Web of documents". Berners-Lee, Hendler, and Lassila [5] describe the evolution of the existing Web into a "Semantic Web", presenting a scenario about what it will be like when Semantic Web agents can respond to human requests, connecting information from various sources and presenting it to the user. The Semantic Web is called a "Web of data" because it provides machine-processable data, and Berners-Lee et al. declare that "The Semantic Web is not a separate Web but an extension of the current one, in which information is given well-defined meaning, better enabling computers and people to work in cooperation" (p. 37) [5]. The "meaning" mentioned above is to be expressed using RDF, and Berners-Lee et al. also predict that machine-processability will increase.

To be digitally usable, the NSDs must be machine processable, meaning that computers and applications must be able to extract meaning from the content without specific prior "knowledge" of the contents. A prerequisite for data to become machine processable is that it be machine readable, and machine-readable data must be structured. Documents scanned as PDFs or Word documents are examples of unstructured data (see Table 1).

Table 1: Types of Data

Type of data	**Example**
Unstructured data	Scanned document, email body
Structured data	Database
Machine-readable data	Data as XML
Machine-processable data	Data as RDF

Extensible Markup Language (XML) is a tag-based metamarkup language for representing structured information. XML derives from standards for creating structured markup in text documents, such as SGML [12], and requires that users define what element names and attribute names should be used and how they should be interpreted. This makes an XML document an example of structured data that is machine readable but not machine processable, as it represents only syntax and not semantics (i.e. the meaning of concepts). To represent semantics, a separate set of rules for how a concept should be interpreted is needed. As the same attribute names and property names can be used in different XML documents with different sets of rules, it is difficult for applications to extract meaning from data originating from different XML documents [3].

The Resource Description Framework (RDF) is a World Wide Web Consortium (W3C) specification designed for representing metadata about Web resources, for example, title, author, and copyright information. In RDF, metadata comprise sets of statements in which each statement, often called a "triple", consists of a subject, predicate, and object. A statement describes a property of a resource, and a metadata description of a resource can be created by combining multiple statements. The subject is the resource to be described while the predicate defines the relationship between the subject and object; as an example, an excerpt of the core content of the syllabus of mathematics is represented below:

Subject	**Predicate**	**Object**
"Methods for solving equations."	is a	core content

Both the subject and predicate are identified by a uniform resource identifier (URI) in order to be uniquely identified. The subject URI identifies the resource and the predicate URI comes from a vocabulary [15]. The value of the property, the object, can be a URI or a literal value, for example, a number or a string. Because RDF uses URIs to identify the subject and predicate, it ensures that each application using the information can retrieve the meaning of the concept and that each concept is unique [5].

Simply stated, XML defines syntax while RDF defines semantics; an XML syntax for representing RDF, i.e. RDF/XML [2], is widely used. By using that format, data are both machine readable and machine processable and thereby digitally usable.

The example above expressed as RDF/XML, where the object is the URI of the description of the type CoreContent, is as follows:

```
<http://wild.edusci.umu.se/wild-dev/matematik/CI_67>
<http://www.w3.org/1999/02/22-rdf-syntax-ns#type>
<http://purl.org/org/wild/schema/core#CoreContent>
```

Linked Data, often seen as a subset of the Semantic Web, "refers to a set of best practices for publishing and interlinking structured data on the Web" (p. 7) [11]. In 2006, Berners-Lee [4] presented four principles to apply to data in order to call them Linked Data:

1. Use URIs as names for things
2. Use HTTP URIs so that people can look up those names.
3. When someone looks up a URI, provide useful information, using the standards (RDF*, SPARQL)
4. Include links to other URIs. so that they can discover more things.

By following these principles and using, for example, URI, HTTP, and RDF standards, the data will be machine processable as well as digitally usable. In 2010, Berners-Lee [4] developed a five-star model (Figure 1) for Linked Open Data (LOD), which essentially constitute Linked Data available with an open license.

Figure 1: Five-Star Model of Linked Open Data (figure based on the Berners-Lee model [4])

The first star of the model is achieved by having the data available on the Web under an open license. Documents can be digitally available in many ways, for example, as scannings, PDFs, Word documents, and Web pages. These are all examples of unstructured data documents that may be usable by humans but not by machines. Today, the Swedish NSDs are available at the level of the first star. When data are available as machine-readable structured data, the second star is achieved, and to reach the third star, data must be available in non-proprietary formats. The fourth star indicates the use of open standards to identify things, so that people can point at your data. At this level, the data are linkable data, i.e. data provided in a way that allows others to make connections to them, though the data themselves do not contain any connections to other data. The fifth star is achieved when data are linked to other data to provide context, producing what are called Linked Open Data.

Linked Data will make it easier to discover, combine, and process data from various data sources. Today we can see examples of this when we search with Google using Rich Snippets to identify structured data related to search results [19]. Another example is the DBpedia project that extracts structured information from Wikipedia and makes it available so that it can be used by Semantic Web applications [1]. As mentioned above, Linked Data concern structured information, but what about unstructured information? As most information on the Internet is unstructured, i.e. textual Web pages, attempts have been made to automatically mark up such information to make it Linked Data [8, 18]. The results depend on the information and methods used, and there is currently no way of automatically achieving complete markup.

To make NSDs machine processable, they need to be made available in a structured machine-readable format. This must be done in a way that makes it possible to extract meaning from the content without prior knowledge of it. The possibility of identifying and connecting separate parts of NSDs to other data would make them usable from a user perspective as well. Dividing NSDs into small entities and adding adequate metadata in the form of RDF statements describing each entity could achieve this. This would require a method to analyze NSDs in terms of both how to divide them and how to determine what metadata are adequate.

4. Methods Leveraged

In focus of the study presented are the subject syllabi incorporating knowledge requirements for Swedish compulsory school [22]. These documents were chosen because of their clear connections to daily school activities in terms of aims of the subjects, content to be taught, and the knowledge requirements that govern grading.

To create a markup that could be useful for more than just compulsory school subject syllabi, the curricula for preschool, compulsory school, and upper secondary school, including course syllabi, were examined to determine the type and structure of the content. The compulsory school curriculum [22] describes its constituent parts, which form the basis of dividing the various types of text in the subject syllabi and the knowledge requirements for compulsory school. Various properties, such as education level and grade level, related to the documents were identified and their relevance to the various parts of the subject syllabi and knowledge requirements was examined.

To create digitally usable versions of the syllabi, their content needs to be divided into meaningful chunks of text; these constitute resources that are individually identifiable and hence useful to machines in the sense that they are useful to NSD users. Creating statements that describe these resources calls for the use of appropriate, relevant properties and terms. The recommendation when modeling data is to reuse predefined vocabularies, as this helps machines automatically find connections between datasets. If no useful properties or terms can be found, new ones can be defined and the definitions should be made accessible on the Internet.

The syllabi and knowledge requirements were marked up with the aim of providing these documents in a digitally usable format. Based on the analysis of the NSDs, various vocabularies and metadata schemes were examined in order to find relevant properties and terms. When no existing relevant properties or terms were found, new ones were defined. The XML syntax for representing RDF, i.e. RDF/XML, was used for the markup, ensuring that the data were in a digitally usable format.

The results of the markup process are NSDs represented in RDF/XML, the actual text content of the NSDs being included in the markup. The resulting data were made available through an open Representational State Transfer (REST) Application Programming Interface (API). REST was chosen because of its lightweight access and potential scalability [25]. The API was used in a 2012–2013 pilot project in which a commercial educational company implemented a system that used the REST API to access the NSD markup. The company connected its learning content to separate parts of the NSDs, allowing teachers to search for learning content connected, for example, to specific core contents and specific years. Since pedagogues tested their digital service both the markup, the API and the pedagogical effects of the markup were tested. The implementation was done using agile development methods with multiple iterations in which feedback from testing led to changes in both the markup and the API.

5. Results

Analysis of the curricula for preschool, compulsory school, and upper secondary school revealed a need for entities describing different types of documents. A main class called "Document", similar to the ASN standard "document", with subclasses for each type was used [7]. The subclass used in this project was "Syllabus".

To make connections to separate portions of the documents, each sentence was regarded as a resource and assigned a unique URI. Exceptions were made for bullet point lists in which each bullet point, regardless of how many sentences it contained, was assigned a unique URI.

The content of the compulsory school syllabi and associated knowledge requirements can be divided into types based on the different parts of the text. A main class called "Statement", similar to the ASN standard "statement", with subclasses for each type was used. The introductory text consists of a short justification of that subject's presence in school. This section of the text is general in nature, pointing to benefits for individuals who master the subject. As this text, unlike the other parts of these documents, is only informative and introductory in nature, it is necessary to define "Introduction" as a type of this information.

The next part of each syllabus is the aim of the subject, which ends with the long-term goals. The long-term goals are stated in a bullet-point list in which each item specifies a different subject-specific ability. The rest of the aim is written in running text and defines the responsibilities teaching has for students to develop the knowledge and abilities listed. In the first version of the markup, both the aim and long-term goals were marked "Aim". Feedback from users of the pedagogical system in the pilot project indicated that the long-term goals were referenced by teachers as abilities and should be separable from the rest of the aim. This led to a change in which “Aim” is used for the aims expressed in running text and “Ability” is used for the long-term goals.

The core content is the next part of each syllabus; it specifies the minimum content to be covered in the teaching and is divided into knowledge areas and according to school year. For this type of text, a “CoreContent” type is defined. In the first markup, this type was named “CentralContent” due to ambiguities in various materials from the National Agency of Education.

Each subject has knowledge requirements related to the long-term goals and core content of the subject. For most subjects, the knowledge requirements state the minimum acceptable knowledge for year 3, defining the level of knowledge required for letter grades A, B, C, D, and E in years 6 and 9. The “KnowledgeRequirement” type is defined to describe this part of the document.

Each syllabus together with the related knowledge requirements relates to one subject, which raises the need for a predicate specifying the subject. The Dublin Core Metadata Initiative (DCMI) [6] maintains some of the most commonly used metadata terms, among which is the term “Subject” intended to represent the topic of the resource. A property named “schoolSubject” was created as a sub-property of Subject representing only school subjects. As the intention is that the DCMI term Subject be used with non-literal values [6], there is a need for a vocabulary specifying the school subjects present in Swedish compulsory school [7]. The NSD markup fulfills the requirement for the fourth star in the five-star model of Linked Open Data described above, meaning that it constitutes Linkable Data. Some of the subjects are unique to Sweden, for example, “Home and consumer studies” and “Swedish as a second language”, while others exist in other countries. The declaration of these subjects includes links to their definitions, making the vocabulary fulfill the requirements for the fifth star in the five-star model and thus constituting Linked Data.

Parts of the text in the syllabi and knowledge requirements are intended for different years, meaning there is a need for a property declaring the school year. This is covered by the DCMI term “educationLevel”. In the syllabi, the aims and abilities apply to all years while the core content applies to the year ranges 1–3, 4–6, or 7–9. The knowledge requirements apply to single years, meaning that to add appropriate markup to the various parts of the syllabi, the year needs to be defined for each single year and it must be possible to specify multiple years for each statement. This is achieved by using the term educationLevel and by creating a vocabulary defining the different school years available in Sweden [7].

As stated above, the knowledge requirements for years 6 and 9 describe the level of knowledge required for different grades. This raises the need for a “gradeLevel” predicate and for a vocabulary specifying the grade levels present in Sweden [7].

To represent the hierarchical structure of the documents, the predicates “hasChild” and “isChildOf” from the Gem Element Set Qualifier Vocabulary [20] are useful for making the structure traversable by positioning the statements within the document. However, it must also be possible to state which document a statement is part of, for which the predicate “isPartOf” from the DCMI terms is used. DCMI has a term “description” that fits the text part of the statement as a text string.

To lower the threshold for using the digitized NSDs, a metadata model is provided [7] stating the properties available for the various types and whether they are repeatable and mandatory. The metadata model can be used in further work on marking up NSDs and also may be helpful to implementers of digital services using the NSD markup.

6. Discussion and Conclusions

The method for analyzing NSDs described above and applied to the syllabi and knowledge requirements for Swedish compulsory school illustrates how NSDs can be analyzed and what markup needs to be added to make them digitally usable. Both public and private schools in

Sweden use the documents that were analyzed and marked up. The Swedish NSDs are very similar in the different school forms, such as compulsory school, upper secondary school, and adult education. Taken together, this means that the method developed for analyzing and marking up NSDs is very significant for the process of digitizing the NSDs governing Swedish schools. The method may be applicable to school NSDs in other countries as well as to other types of text document, provided the documents have clear distinctions regarding their types of constituent text.

One disadvantage of providing the digitized NSDs as a Web-based service is the vulnerability arising from the standalone server used. This could be eliminated by using multiple servers and load-balancing software or using an approach involving microservices. The pilot project demonstrated that the NSD markup, choice of technology, and implementation techniques all affect what teachers can do with the digitized NSDs.

During the study, contacts with school leaders, teachers, and representatives of the National Agency for Education involved in another project yielded valuable information regarding their needs in terms of what kinds of data from the NSDs are of interest in their ongoing work. This information influenced the NSD markup because it gave a better understanding of the needs of school actors in relation to digital services for school.

Having NSDs in a digitally usable format in the form of a Web service makes the NSDs part of a global information ecology for school that enables many digital services connected to various parts of NSDs. As more school resources become available in a digitally usable format, it is important that the markup should contain links to other datasets to allow comparisons not yet imagined. This would permit a wide range of data types connected to NSDs capturing, for example, work activities in apprenticeship education, individual development plans, and digital learning resources. In Sweden, a brokerage service for learning resource repositories, the Spider, makes digital learning resources from various repositories available for searching [16] to facilitate teachers and learners. By adding NSD connections to learning resource metadata, it would be possible to search for learning resources relevant to specific knowledge requirements or core contents. Putting all this together could help schools and teachers document student progress in relation to NSDs. Being able to visualize the parts of a syllabus a student has fulfilled and the parts needing more attention could prevent individual parts from being neglected. This also permits a scenario in which a student can search for digital learning resources based on the specific parts of the syllabus he/she needs to work more on according to his/her teacher. School NSDs could also be connected to the steering documents of various lines of business and professions, making it possible to see where their steering documents and school NSDs overlap. Identifying such overlaps could allow students to get credit for everything they have achieved during apprenticeship education.

From an international perspective, digitally usable NSDs could make it easier to compare NSDs from different countries. If steering documents from different countries were connected through their markup, digital learning resources connected to steering documents in one country could automatically be related to relevant parts of other countries' steering documents and thereby be available to NSD users in that country. Today, many comparisons are made between countries regarding their Programme for International Student Assessment (PISA) results. By relating digitized steering documents from various countries to each other, it would be easier to analyze PISA results in relation to various countries' steering documents. The key issue when creating relationships between countries' steering documents is finding similarities. School NSDs in Scandinavian countries are somewhat similar, making it possible to connect parts of these countries' steering documents to each other, provided they are available in a digitally usable format, as in the case of the US achievement standards mentioned above [9].

Future research into digitizing Swedish NSDs could extend the metadata model to include all NSDs, such as the Curriculum and Educational Act.

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