Linking Learning Resources to Curricula by using Competencies

Frans Van Assche

European Schoolnet
frans.van.assche@eun.org

Abstract. While a lot of digital and non-digital educational resources exist, teachers still struggle to find the ones that appropriate for the curriculum they are teaching. The problem is very much compounded when dealing with a multicultural, multilingual environment, such as Europe where dozens of curricula exist in isolation. This paper presents a solution whereby first competencies are proposed as a common denominator for curricula, and second the competencies are presented in the IEEE LOM standard. This approach allows teachers to tag a resource according to their own curriculum while A, where other teachers can find it back using their local curriculum B. The paper presents a full implementation of this approach and first findings of the results.

Keywords: curricula, semantic interoperability, competency-based education, learning resource discovery, learning object metadata

1 Problem statement[1]

While much progress has been made in improving semantic interoperability in order to discover, evaluate, and use learning resources, teachers in primary and secondary schools have constantly and consistently pointed to the requirement of being able to do this in terms of their national/regional curriculum.

More in particular, given that a resource is properly metadata tagged using one national/regional curriculum, can the resource be discovered and can the metadata be shown to another teacher in terms of her own national curriculum, such that it eventually can be used in order to meet the goals of the teacher's national/regional curriculum?

[1] This research is part of the CALIBRATE project which among other things researches machine-readable descriptions of national curricula and investigates mapping approaches that can improve the semantic interoperability between systems in the discovery, evaluation and use of learning resources.

The CALIBRATE project [6] considers four approaches for solving this problem:

- resources are metadata tagged according to all (an estimated 50 national/regional) curricula in Europe alone. This is very expensive in initial tagging and maintenance.
- a mapping is provided between the different curricula such that if a resource is metadata tagged according to one curriculum (e.g. the Flemish curriculum), it can be discovered and shown in terms on another curriculum (e.g. the Austrian curriculum) . A curriculum mapping (see [7], [8]) means that a component of one curriculum can be mapped to a boolean expression of components of another curriculum. This mapping can be done in two ways: relating all curricula pair wise to each other or relate all curricula to a common spine.
- resources are metadata tagged according to a spine or universal curriculum. This approach is workable but is not really meeting the objectives of allowing the teacher to browse according to her own curriculum unless a mapping is made between the specific national/regional curriculum and the spine.
- all countries and regions adopt the same curriculum. This is politically not feasible in the short nor middle term.

Hence, a mapping approach between curricula (option 2) is explored.

Apart from the mapping challenge there is the question of relating curricula to educational content both for metadata tagging and for discovery. So essentially the challenge covered in this paper is threefold:

- how can we map curricula to each other. This deals with the semantic interoperability of curricula in order to avoid the tagging of learning resources according to all existing curricula.
- how can we relate curricula to resources. This in order to offer teachers to discover, evaluate, and use resources in terms of their familiar curriculum.
- how can we find resources based on curricula and competencies.

2 School Curricula

Curricula should be considered at different levels as depicted in figure 1 [6] . At the government level, it might be the national or the regional government that determines the curriculum. At the sub-governmental level it might be school networks, or Local Educational Authorities, or even publishers that elaborate the curriculum further. At the school level, the school may decide to have a single base curriculum for a programme of study. At the teacher/learner level a teacher will typically develop a

year plan. Usually the lower level will be consistent (i.e. not contradicting) a higher level. Furthermore not all levels may be defined.

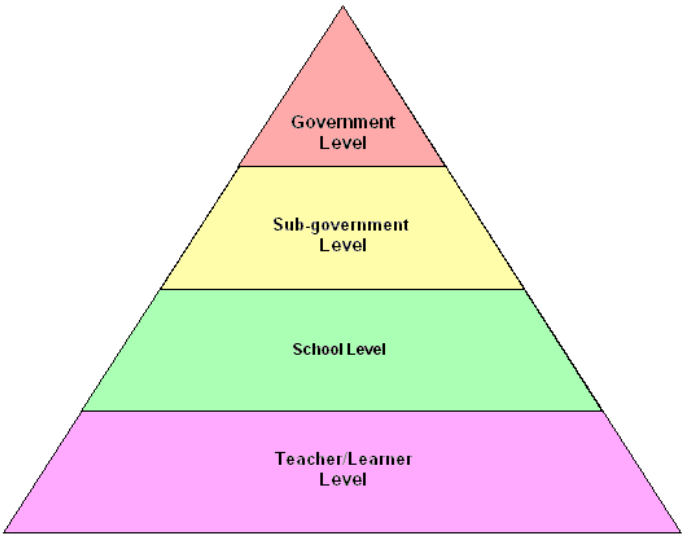

Fig. 1. Curricula at different levels

Typically, a teacher will consider at least two levels: the teacher level, often in the form of a year plan) and the curriculum level she bases her year plan on to. For example it might be that a teacher is developing her year plan on the basis of the regional curriculum. Alternatively she uses the school curriculum for her subject where the school has adopted a curriculum as proposed by a publisher. In the latter case she will still know very well the national/regional curriculum.

3 Interoperability of curricula

Curricula may contain a number of elements but the most important element is the set of educational goals. The best way to establish interoperability is, in our opinion, to translate these goals into a common language. Obviously, if a goal can be broken down in smaller parts, the likelihood of finding common ground is higher than when using more complex goal expressions.

One way of breaking down educational goals is expressing them as targeted competencies. For example, the goal "The pupils know the symbol rules for whole and rational numbers" from the Flemish curriculum on Mathematics, refers to two competencies: "know (or recall) symbol rules for integers" and "know (or recall)

symbol rules for rational numbers". On the other hand goals might be defined in terms of certain activities to be done. For example, one of the goals of the Austrian curriculum for mathematics reads "Arbeiten mit Primzahlen und Teilern, Untersuchen von Teilbarkeitsfragen" (work with prime numbers and divisors, examining divisibility questions). Again this could be broken down into a number of activities such as "work with prime numbers", "work with divisors", "examining divisibility questions".

In our approach we favour competencies as the basic building block and this for two reasons: (a) it is easier to understand the targeted competencies behind an activity than the other way around; which indicates that competencies are more elementary, and (b) eventually learners will be assessed and this will usually be done by testing whether learners can solve problems requiring certain competencies.

Competencies have been part of educational research already for some time (see [5]) and it is expected to grow in importance and the emergence of life-long learning is obviously not foreign to this. While many definitions of competencies exist, this paper follows more closely the definition as used in the Learning Technology standardization world, i.e. as any form of knowledge, skill, attitude, ability or learning outcome that can be described in a context of learning, education or training. As such it follows the distinction as made by Chomsky[2] between competency and performance. While a more specific definition is possible, the above is sufficient in the context of this paper.

4 Interoperability of competencies

Thus, the principle part of a curriculum, is what students should learn expressed as targeted competencies. The basic building blocks for targeted competencies in our approach are: an action verb expression and one or more topics. The topic might for example be 'adding fractions' and the action verb expression might be 'understanding' or 'applying'. As such competencies can be expressed as a tuple of the form

$$c = < v, \{t_1, \ldots, t_n\} >$$

where ‘c’ stands for competency, ‘v’ for an action verb expression and ‘t_1, …, t_n’ are topics. Usually there would be only one topic, but occasionally there will be more than one. For example: ‘understand multiplication of rational numbers’.

The elements of the tuple come from two taxonomies: a topic taxonomy and an action verb expression taxonomy. Hence the problem of interoperability of curricula is reduced to the interoperability of these topic and action verb expression taxonomies and this is the key to the solution as it avoids a too complex spine to which curricula should be mapped. The relationship between the different taxonomies is given in figure 2.

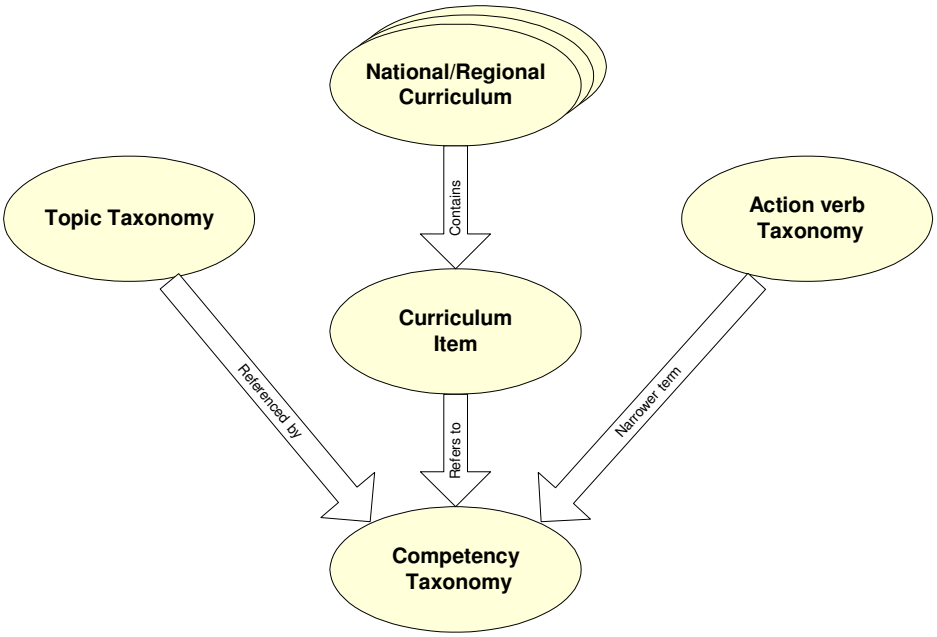

Fig. 2. Relationship of curriculum items and taxonomies

So the first step is to translate the goals of curricula into competencies. As an example, below follows an excerpt of the Flemish curriculum. The competencies added are given in italics. Within the competencies, the topics are underlined.

MATHEMATICS

1 Content attainment targets

1.1 Number theory

1.1.1 Concept formation/knowledge of facts

1 The pupils can associate natural, whole and rational numbers with realistic and meaningful contexts;

- *Associate natural numbers with real and meaningful context*
- *Associate integers with real and meaningful context*
- *Associate rational numbers with real and meaningful context*

2 The pupils know the symbol rules for whole and rational numbers

- *Recall symbol rules for integers*
- *Recall symbol rules for rational numbers*

3 The pupils know that the properties of the operations in the set of natural numbers remain valid and can be expanded in the sets of whole and rational numbers

- *Relate properties of operations for natural numbers to properties of operations for rational numbers*

4 The pupils distinguish and understand the various notations of rational numbers (fractional and decimal notation)

- *Distinguish notations of rational numbers*
- *Understand notations of rational numbers*

An excerpt of the action verb expression taxonomy following the revised Bloom's taxonomy extended with competencies looks as follows:

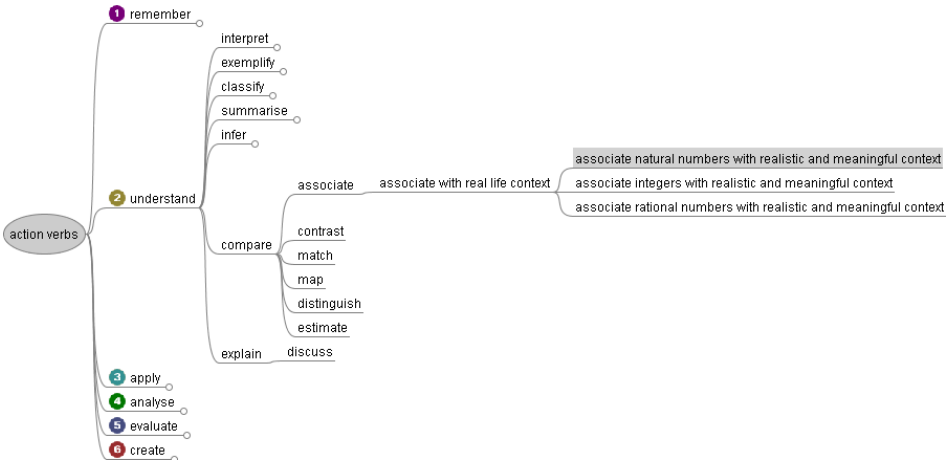

Fig. 3. Action verb expressions based on a revised Bloom taxonomy extended for competencies

As one can see the expression 'associate' has a narrower term 'associate with real life context' which in turn refers to three more terms which are competencies.

Further refinements are possible by taking different action verb expressions for different topic categories. For example the action verb expressions for mathematics could be different from the action verb expressions for languages. However, this exercise might turn out to be just a scoping of the proposed action verb expression taxonomies based on [1], [3], [4].

The second part of the solution is that competencies are referenced by terms in the Topic Taxonomy. For example 'associate natural numbers with real and meaningful context' references the term 'natural numbers'.

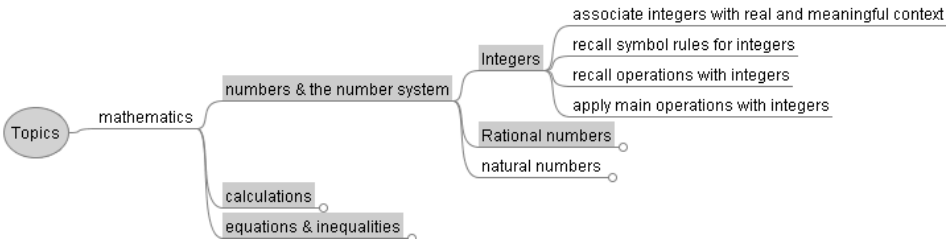

Fig. 4. Topics extended for competencies

Semantic interoperability is thus achieved by first expressing curriculum items in terms of targeted competencies, and second by expressing these competencies as tuples of action verb expressions and topics which both can be drawn from a controlled vocabulary.

The fact that two simple controlled vocabularies are used for expressing competencies allows for translation in other languages as well as automatic relaxing search criteria. For example if no resource could be found matching the competency “associate integers with real and meaningful context” then it could be relaxed to “associate numbers with real and meaningful context” climbing up the Topic taxonomy. Similarly it could be relaxed by climbing up the Action verb expression taxonomy giving a potential match with “compare integers”. This relaxing mechanism also allows to map curricula even if there is no perfect match.

5 Linking Curricula to Content

Linking curricula to content can be done in two ways:

1. An explicit relationship is established between a learning resource and a curriculum item. For example learning object 52418 is said to be relevant

for the curriculum item "The pupils know the symbol rules for whole and rational numbers". More in particular - using concepts from set theory: the relationship is defined between a resource and the extension of a set of related curriculum elements. The extension of a set comprises the members of a set. Alternatively, the relationship is defined between a curriculum element and the extension of a set of related resources. This can be done as metadata tagging of a resource or the curriculum element. For example a librarian or teacher indicates for which curriculum element the resource under consideration could be used. This may happen before or after discovery/evaluation, or use.

2. The relationship between a curriculum element and a resource is defined by intension. I.e. The relationship is defined between a resource and the intension of a set of related curriculum elements. The intension of a set is its description of defining properties, i.e. what is true about the members of the set. The set of related curriculum elements could for example be described in terms of targeted competencies assuming that a curriculum element is suitable for the development of one or more competencies. A second way of establishing the relationship between a curriculum element and a resource by intension is that for a given curriculum element the properties of possible related resources are given. For example age, language, subject, targeted competencies of the resource. The properties that can be used for the describing a set of resources and that are possible related to a curriculum element are: Keyword, Coverage, Structure, Aggregation Level, Interactivity Type, Learning Resource Type, Interactivity Level, Semantic Density, Intended End User Role, Context, Typical Age Range, Difficulty, Typical Learning Time, Language, Classification (purpose being discipline, competence, or activity). Again, establishing the relationship may happen before or after discovery/evaluation, or use.

In the CALIBRATE project [6] the experiment set up is linking a resource in an extensional way to a curriculum item or a competency. The way this is done is by giving the users the opportunity to browse the curriculum and indicate where a learning resource - e.g. identified through search or browsing – can be used. The CALIBRATE project provides this opportunity to both curriculum experts as well as casual users such as teachers. By doing the latter, social tagging is introduced where the tagging process is guided through controlled vocabularies related to competencies.

Hence teachers can indeed browse their own national/regional curriculum and find learning resources that are useful in attaining the educational goals and to develop the underlying competencies (see figure 5).

Fig. 5. Browsing the curriculum finding suitable learning resources

Figure 6 demonstrates how the IEEE standard for Learning Object Metadata (LOM) is used for storing the metadata concerning competencies related to the curriculum. The competencies are stored in section 9.1 of the LOM where it is indicated that the classification concerns a competency and in section 9.2 where terms from an action verb multilingual thesaurus, and from a topic multilingual thesaurus are stored.

Within the project these two thesauri were developed. The action verb thesaurus according to Bloom's revised taxonomy and a topic thesaurus for the subjects

Mathematics and Natural Sciences. The thesauri are multilingual thesauri and the competencies can be recorded also in a multilingual way.

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  <purpose>
    <source>LOMv1.0</source>
    <value>competency</value>
  </purpose>
 <taxonPath>
    <source>
      <string language="en">LRE ActionVerbThes</string>
    </source>
    <taxon>
      <id>act_3</id>
      <entry>
        <string language="en">understanding</string>
        <string language="nl">begrijpen</string>
      </entry>
    </taxon>
  </taxonPath>
  <taxonPath>
    <source>
      <string language="en">LRE TopicThes</string>
    </source>
     <taxon>
      <id>top_5</id>
      <entry>
        <string language="en">multiplication</string>
        <string language="nl">vermenigvuldigen</string>
      </entry>
    </taxon>
    <taxon>
      <id>top_6</id>
      <entry>
        <string language="en">rational numbers</string>
        <string language="nl">rationele getallen</string>
      </entry>
    </taxon>
  </taxonPath>
</classification>
```

Fig. 6. Example of LOM metadata holding competencies related to a resource.

6 Conclusion

The approach makes interoperability possible by making use of two smaller controlled vocabularies instead of a very large one on competencies which would be more volatile.

The approach builds on proven technologies, i.e. thesauri, and well-known vocabularies for the action verb expressions and allows for relaxing the search criteria building upon the hierarchical structure of the two vocabularies.

The approach can be used for tagging by experts indexers as well as for social guided tagging where the guidance comes from the multilingual thesauri provided.

The approach is resilient to change in curricula and to the addition of new curricula. Even a teacher could determine her year plan and be automatically interoperable as long as the year plan is specified in terms of tuples (indicating competencies) of action verb expression and topic(s) which are a subset of the Cartesian product of the terms in the two vocabularies: topic and action verb expression.

The approach fits very well with the current practice of describing learning objects. Indeed section 9 of the IEEE LOM standard can be used without alteration. For LOM data element 9.1, indicating the purpose, the value 'competence' should be used.

One condition to be fulfilled is that curricula are expressed as competencies, which is not always the case. Sometimes they are expressed as activities to be undertaken or simply as subjects to be taught. In that case the targeted competencies should be researched or interoperability can be restricted to the topic vocabulary.

In conclusion we can say that the distinct features of the approach as described in this paper, makes it very promising and therefore it was no surprise that the first tests in practice held with curriculum experts in the spring of 2007 were indeed successful. Curriculum experts were indeed able to express curricula in terms of competency tuples and teachers confirmed the usefulness of finding resources on the basis of curriculum items and/or competencies.

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