Design of Achievement Standards Linked Data Profiles Connecting Curricula and Digital Content

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***Abstract*—Achievement standards are a practical basis of teaching/learning and assessment defined by national education organizations. Achievement standards provide practical guidelines about what has to be taught and assessed by teachers and what has to be studied and achieved by students. The educational jurisdictions, however, provide achievement standards as unstructured and textual documents, which are inappropriate and inefficient for selective searching, sharing, and usage of statements. In this paper, we design an ontological semantic model of achievement standards and define mapping rules to formalize the semantic model to RDF/OWL specification, which is based of linked open data. Our proposed semantic model is a fundamental element to implement an achievement standards linked data profile that supports the statements searching and browsing, sharing, modification history tracing, learning resource linking, and mapping and integration of heterogeneous standards.**

***Index Terms*—Achievement standards, Statement, Linked open data, Education, Assessment**

I. Introduction

UP until now, most learning support systems have provided collection and storage functions of learning resources and supported the listing and searching of the learning resources on the basis of learning objects, i.e., school subjects. This paper discusses a different perspective from the conventional one, namely, a method of linking the curriculum, teaching/learning plans, and learning resources with each other on the basis of achievement standards[1][2]. According to the 2009 Revised National Curriculum of Korea, achievement standards are defined as "a statement of the ability and characteristics of knowledge, skills, and attitude that students must achieve through learning, to be presented as a practical basis of teaching/learning and assessment." In other words, achievement standards provide practical guidelines about what has to be taught and assessed by teachers and what has to be studied and achieved by students, and as shown in Fig. 1, they are used as criteria in teaching/learning and assessment according to the characteristics and aim of the education curriculum [3].

The establishment and enforcement of the national achievement standards started from the 7th Education Curriculum and has been expanded and improved in terms of quantity and quality through the 2007 and 2009 versions of the Revised Education Curriculum [4]. Particularly, the curriculum development policy of the 2009 Revised Education Curriculum strengthened the quality of the education curriculum through school curriculum assessment, school subject general assessment, and national achievement assessment. Accordingly, teaching method research, development, and support activities are continuously carried out to develop and deploy the achievement standards and achievement levels by school subject and provide various assessment methods, processes, and tools [5].

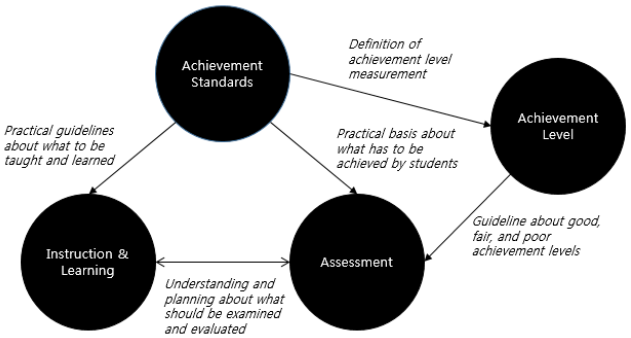

Fig. 1. Meaning of achievement standards.

The form of content achievement standards for each school subject is a combination of knowledge, skills, and attitudes that students must achieve through learning, and the behaviors and characteristics of learners; it is composed using behavioral terminologies to describe study contents from the perspective of students and clearly reveals the behaviors that must be achieved. For example, "Lesson 9052. When the temperatures of two objects in contact are different, the heat transfer between the two objects to reach thermal equilibrium can be explained" is one of achievement standards defined in the "Matter and energy" unit in middle school science.

The 2009 Revised Education Curriculum was applied to the first and second grades of elementary school and the first year of middle school in 2013, and it will be extended to the other grades and school subjects year by year for the application of the achievement standards curriculum across all grades and subjects by 2016. Therefore, it is necessary to build a system that can support achievement

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standards–oriented teaching/learning, with the aim to structuralize, share, and interconnect the achievement standards data for all school subjects.

It is necessary to convert the contents of achievement standards distributed presently in a document format for each subject into a data structure that a machine can process through conversion to data and hierarchical structuralization. However, the conversion into a database through an entity relationship diagram (ERD) design can stop at simply supporting data storage and search. By implementing RDF/OWL-based linked data, an interconnection-oriented data cloud between various types of learning information and resources can be established and an achievement standard–based intelligent teaching/learning service can be implemented. Also, through the connection with foreign achievement standards linked data, advanced services can be implemented, such as comparison, review, improvement, and linkage of achievement standards.

This paper is organized as follows. In Section 2, the concept and trend of linked data are introduced, and in addition, the Achievement Standards Network (ASN), which is the achievement standards repository of the U.S., is introduced. In section 3, the comparison between ASN and Korean Achievement Standards is described. In Section 4, the design and utilization method of the linked data-based achievement standards profile are introduced, and in Section 5 a conclusion is provided.

II. Related Work

Linked Open Data (LOD,) or simply linked data, are created by interconnecting data by assigning a dereferenceable URI (Unique Resource Identifier) to them and meaning links (e.g., sameAs) as a method of building a Web of data. In other words, linked open data can be understood as a combination of open data and linked data. Open data mean that the data are open on the Web and anyone can access or reuse them through the HTTP protocol, and linked data are independent data linked by meaning relationships, which can expand and mash up knowledge [6][7].

Liked open data do not indicate a new technology, they are implemented with Web standard technologies such as HTTP, URI, RDF, and SPARQL, which are conventional Semantic Web–based technologies. The core of the Semantic Web's success lies in the construction of an ontology-based inferable knowledge base, but it is a very slow and complex work that requires much time and effort. Therefore, compared to the vision of the Semantic Web, realistic success cases and uses are very slow and because of this, the Semantic Web is sometimes regarded as a failure[8].

The method of creating linked open data follows the ontology modeling process in ontology methodology. Through data analysis of the domain where the linked data are to be constructed, the concept words are extracted and defined, and a concept dictionary is composed. Based on this, the ontology elements such as class, data type attribute, and object type attribute are defined, and each element has a unique referenceable identifier (URI). Afterwards, by generating many trifles according to the RDF syntax and saving them in storage, linked data can be constructed. The important part is not generating independent data, but being added as an element of a linked data cloud through inter-reference link generation for connecting with existing linked data.

At present, studies are being carried out in South Korea and overseas for methods of opening and linking public data on the basis of linked data and utilizing them industrially. The U.S. and the European Union are already preparing legal and institutional systems for a continuous open policy of public data and supporting uses and reuses in the private sector. South Korea has also shown much interest and effort in the construction of linked data for open and reuses of private or public data[9].

The ASN is a linked data repository of school subject learning achievement standards established by U.S. national and state education offices, and provides the hierarchical structure definition of achievement standards and the mapping relationships between mutually different achievement standards for identical school subjects [10]. Furthermore, it provides browsing and search functions of achievement standards and supports the connection of achievement standards with teaching/learning and assessment. The metadata of the ASN profile defines the relationships between the achievement standards by modeling the K-12 achievement standards document and the statement described in the document, in an RDF format. Fig. 2 shows the mapping structure of the ASN and explains the mapping between the achievement standards of each state, such as Texas and California, as well as the linkage with learning resources.

At present, the ASN repository stores more than 700 achievement standards documents for K-12 education established in each U.S. state; and also interconnects and stores not only the achievement standards of private education institutions in addition to the federal and state government data, but also the official achievement standards data of national, state, and regional education institutions in Australia. Currently, there are about 340,000 stored and accessible achievement standard items in the ASN repository[11].

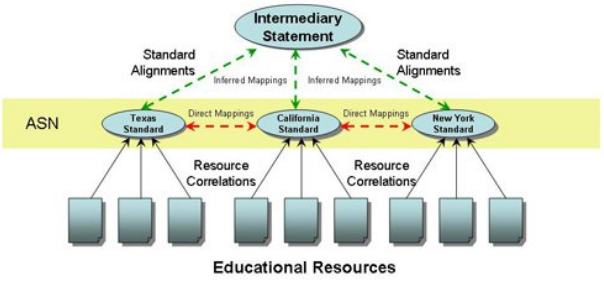

Fig. 2. ASN's mapping of achievement standards and linkage with educational resources.

In the ASN achievement standards profile, the relationship between the achievement standards document and achievement standards is defined by a hierarchical structure. That is, the <*dcterms:isPartOf*> relationship is defined between the achievement standards and the achievement standards document, and the <*gem:isChildOf*> relationship is defined between the achievement standards, generating a taxon path.

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III. Comparison between ASN Framework and Korean Achievement Standards

According to WG4 N2025 'The Achievement Standards Network (ASN) - Framework a Linked Data Approach to Learning Objectives and Educational Content', standards document in terms of curriculum standard and statement in terms of achievement statement have structural relationship like Fig. 3. Through the case study on comparison document scheme between ASN Framework and Korean education system, researchers could find common similarity (in fact, almost same) that achievement statement as set of competency requirements is derived from curriculum standard.

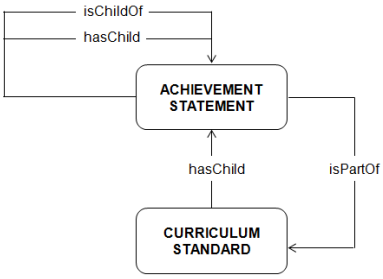

Fig. 3. Structural relationships between achievement standards and statements.

Properties of Matter — How does the structure of matter affect the properties and uses of materials?

PREKINDERGARTEN

PK.1 - Objects have properties that can be observed and used to describe similarities and differences

Core Science Curriculum Framework	Preschool Curriculum Framework	Grade-Level Expectations *Students should be able to:*	Preschool Assessment Framework
PK.1.a. Some properties can be observed with the senses, and others can be discovered by using simple tools or tests.	Cognitive Development: Logical-Mathematical/Scientific Thinking - 1. Ask questions about and comment on observations and experimentation; 2. Collect, describe and record information; 3. Use equipment for investigation; 4. Use common instruments to measure things; 5. Demonstrate understanding of one-to-one correspondence while counting; 6. Order several objects on the basis of one attribute; 7. Sort objects by one or more attributes and regroup the objects based on a new attribute; 8. Engage in a scientific experiment with a peer or with a small group.	1. Use senses to make observations of objects and materials within the child's immediate environment. 2. Use simple tools (e.g., balances and magnifiers) and nonstandard measurement units to observe and compare properties of objects and materials. 3. Make comments or express curiosity about observed phenomena (e.g., "I notice that…" or "I wonder if…"). 4. Count, order and sort objects (e.g. blocks, crayons, toys) based on one visible property (e.g., color, shape, size). 5. Conduct simple tests to determine if objects roll, slide or bounce.	**COG 1** Engages in scientific inquiry **COG 3** Sorts objects **COG 5** Compares and orders objects and events **COG 6** Relates number to quantity

Fig. 4. Example of Connecticut science grade-level expectations.

Korean experts tried to reflect same concept of semantic relationship between outcomes stated in curriculum standard and achievement statement. Because Korean case study is not transform to Linked Open Data format yet, cross subject reference property in achievement statement is just expected relationship, and even if textbook publisher and teachers generally derived outcome statement from achievement statement published by government level, which specific topic is derived from something in achievement statement is not open to public yet. This is the reason why both properties '*crossSubjectReference*' and '*derivedFrom*' are enclosed in parentheses. In this section, document scheme comparison is introduced between source of ASN Framework and Korean curriculum standard and achievement statement. Firstly we picked up one of standard of ASN Framework, Connecticut science grade-level expectations, and analyze structure of the document depicted in Fig. 4.

All data of the standard are registered into ASN Framework and can be browsed each information on the web such as Fig. 5.

Fig. 5. Example of Connecticut science curriculum standard and statement.

In case of Korea, two kinds of document are used to describe curriculum standard and core achievement statement. First, in the curriculum standard area of content per education level (grade group) is decided and achievement criteria and exploration activity per education level is guided in the document. Second, through the achievement statement document each criteria of curriculum standard match to statement of achievement criteria described in Fig. 6.

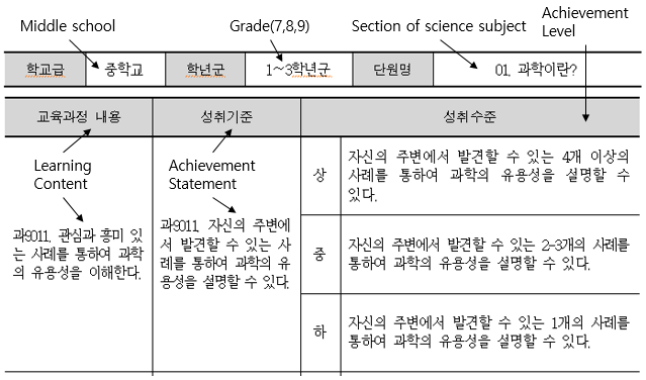

Fig. 6. Example of curriculum and achievement criteria for science subject (in Korea).

The curriculum standard for science subject depicted in Fig. 12 can be interpreted as follows:

- **Title (*en*):** Science subject curriculum
- **Description (*en*):** *(omission)*
- **Publication Status:** Published
- **Subject:** Science
- **Education Level:** K-3, 4, 5, 6, 7, 8, and 9
- **Language:** Korean
- **Source**: http://ncic.re.kr/nation.dwn.ogf.inventoryList.do
- **Date Valid:** 2011
- **Repository Date:** 2012-12
- **Author (*en*):** Ministry of Education
- **Publisher (*en*):** Ministry of Education

In summary, through comparison for document scheme of countries researchers could get insight for similarity of concept model and captured entities and properties to describe curriculum standard and achievement statement. To reach and/or develop International Standard level, this kind of comparison is required for evaluation for the concept and terminology.

IV. Achievement Standards Linked Data Profile

In this section, the achievement standards linked data profile–based service model is defined, and the class design

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of achievement standards linked data profile is introduced to support it.

A. Classes Definition

Through the achievement standards document analysis, we identified the core entities of achievement standards linked data profiles. These entities are defined with the classes of achievement standards linked data shown in Fig. 7. The list of classes for achievement standards linked data profiles is as follows, and Tables 1 to 3 show detailed specifications for core classes, which conceptualize achievement standards and statements.

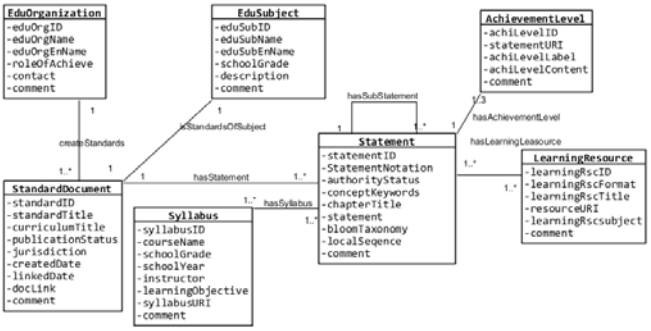

Fig. 7. Achievement standards linked data class diagram.

- **EduOrganization:** An educational institution that composes and manages achievment standards and achievement levels
- **EduSubject:** A subject for which achivement levels are defined
- **Statement:** Achivement standards defined in the achivement standards document
- **AchievementLevel:** Good/fair/poor achivement level for each achievemnt standard
- **Syllabus:** Teaching/learning plan based on the achievement standards
- **LearningResource:** Learning resource related to the achievement standards

TABLE I
STANDARDDOCUMENT CLASS

Description	Definition
Class name	StandardDocument
Class label	Achievement Standards Document
Class type	n/a
Class URI	http://kr.kasn.org/KASN/schema/StandardDocument
Child class	n/a
Explanation	It refers to an achievement standards document defined for each pertinent school subject. It is a class for specifying a document itself that describes the achievement standards, achievement levels, and assessment methods for each school subject. It defines the metadata of document and a link to actual document as attributes.

TABLE II
STATEMENT CLASS

Description	Definition
Class name	Statement
Class label	Achievement Statement
Class type	n/a
Class URI	http://kr.kasn.org/KASN/schema/Statement
Child class	n/a
Explanation	It is a class that defines an individual achievement standard defined in the achievement standards document. The achievement standards consist of curriculum content achievement standards and detailed achievement standards. Since more detailed and specific achievement standards are defined when going down to a child level, this class has a self-inclusion relation to define the hierarchical structure of achievement standards.

TABLE III
ACHIEVEMENTLEVEL CLASS

Description	Definition
Class name	AchievementLevel
Class label	Achievement Level
Class type	n/a
Class URI	http://kr.kasn.org/KASN/schema/AchievementLevel
Child class	n/a
Explanation	It is a class that defines the achievement level by achievement standard. The achievement level is defined in three types of “good/fair/poor”. Considering the expandability, good/fair/poor is defined as an instance of this class instead of as an attribute. That is, for one achievement standard, three (good, fair, poor) achievement standard instances are set up at maximum.

B. Data Property Definition

For each class, we identified core values from achievement standards documents and define data properties as described in Table 4 to 6.

TABLE IV
PROPERTY DEFINITION OF STANDARDDOCUMENT

Property	Type	Description
standardID	String	Unique identifier of standards document
standardTitle	String	Title of standards document
curriculumTitle	String	Course title of standards document
publicationStatus	String	Publication status of standards document(published, draft, revised)
jurisdiction	String	Jurisdiction controlling standards
createdDate	Date	Published date
linkedDate	Date	The date of registration into the linked data repository
docLink	URI	URI of the stored standards document
comment	String	Comment

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TABLE V
PROPERTY DEFINITION OF STATEMENT

Property	Type	Description
statementID	String	Unique identifier of a statement
statementNotation	String	Statement code notation
authorityStatus	Core/Gen	Core or general statement
conceptKeyword	String	Concept words defined in a statement
chapterTitle	String	Chapter or section title of a statement
statement	String	Statement
bloomTaxonomy	URI	Knowledge, skill, or attitude related to a statement
localSequence	String	Sequence no
comment	String	Comment

TABLE VI
PROPERTY DEFINITION OF ACHIEVEMENTLEVEL

Property	Type	Description
achiLevelID	String	Unique identifier of an achievement level
statementURI	String	URI of a statement referenced by an achievement level
achiLevelLabel	Good/Fair/Poor	Category of an achievement level
achiLevelContent	String	Description of an achievement level
comment	String	Comment

C. System Model Definition

The achievement standards linked data profile–based teaching/learning support system is facilitated by linking the achievement standards, learning assessment, and learning resource with the study plan, as shown in Fig. 8. First, in a study plan such as a syllabus, the standards for learning achievement of each school subject are defined by linking them with achievement standard profiles. Also, the assessment items in the syllabus evaluate student achievement based on the achievement levels set up through the achievement standards. Each weekly learning content component of the syllabus has links with detailed learning resources required for studying, and at the same time, the link structure is also defined between the achievement standards and learning resources.

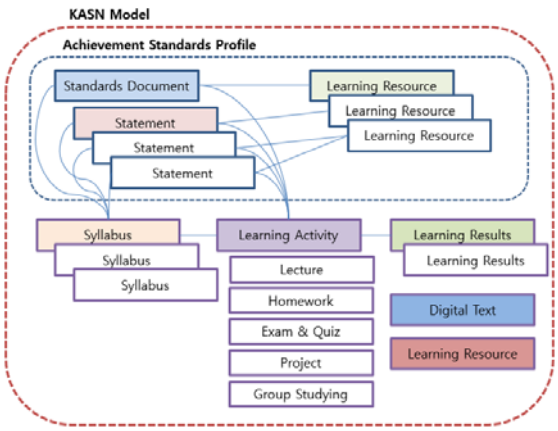

Fig. 8. Links with achievement standards, study plan, learning assessment, and learning resources.

Fig. 9 shows a service model that supports achievement standard–based adaptive learning. The achievement standards are defined with the study objective of the syllabus, and the achievement levels are determined through assessment for learning activities. Measuring the good, fair, and poor achievement levels, learning paths can be generated so that students who do not reach a certain level can repeat the pertinent learning process. First of all, we reference the Boom's taxonomy and define the structure of learning objective class as the following tuple which is composed of five elements, identifier, learning objective, cognitive level, attitude level, and skill level.

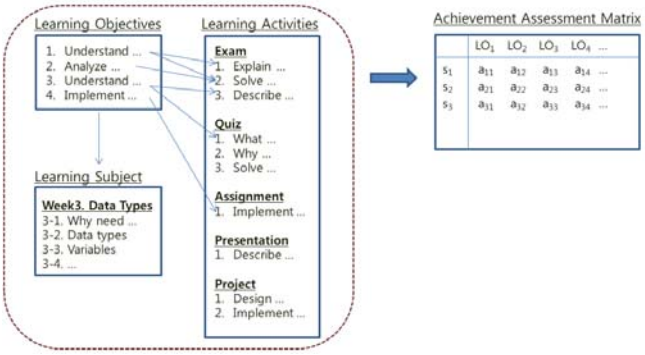

Fig. 9. Achievement standard–based adaptive learning.

$$<ID, obj_i, C_j, A_k, S_p> \quad (1)$$

obj : each sentence of learning objectives
C : a specific cognitive level related to obj_i
A : a specific attitude level related to obj_i
S : a specific skill level related to obj_i

To create interlinks between learning objectives and assignments, we add identifiers of learning objectives to the related each of the assignments. For exams and learning topics, we did the same process to connect with learning objectives. In addition, we create an achievement matrix in order to measure the learning achievements of students for learned topics weekly as well as the entirety of a course as depicted in Fig. 11. In the achievement matrix, the columns are learning objectives and rows are students. Each cell has a value representing the degree of achievement of a certain student against a specific learning objective. From the achievement matrix, we can figure out students who have a lower achievement for each learning objective than a specific threshold, which means a minimum requirement. These unfulfilled students can be guided to study the unachieved topics by the generation of adaptive learning paths. The adaptive learning paths can be generated in different granularity. The high-level learning path can be created using syllabuses and their relationships. The low-level learning path can be created using learning concepts and their relationships defined in the subject ontology.

D. Linked Open Data Specification

In this section, we define a mapping rule for specifying RDF/OWL documents in order to build the KASN Linked Open Data repository. First, we define some namespaces to reference to upper ontologies as follows:

- xmlns:asn="http://purl.org/ASN/schema/core/"
- xmlns:dc="http://purl.org/dc/elements/1.1/"
- xmlns:skos="http://www.w3.org/2004/02/skos/core#

Second, we define a mapping rule shown in Table 7. This

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mapping rule is used for transforming entities of KASN class model into constructs of the RDF/OWL syntax.

TABLE VII
DEFINITION OF BINDING RULES FOR RDF/OWL SPECIFICATION

Description	Definition
EduOrganization	<owl:Class rdf:about="http://kasn.org/schema/core/EduOrganization"/> <kasn:EduOrganization>
EduSubject	<owl:Class rdf:about="http://kasn.org/schema/core/EduSubject"/> <kasn:EduSubject>
StandardDocument	<owl:Class rdf:about="http://kasn.org/schema/core/StandardDocument"/> <kasn:StatementDocument>
Statement	<owl:Class rdf:about="http://kasn.org/schema/core/Statement"/> <kasn:Statement>
AchievementLevel	<owl:Class rdf:about="http://kasn.org/schema/core/AchievementLevel"/>
standardTitle	<owl:DatatypeProperty rdf:about="http://kasn.org/schema/core/dataproperty/#standardTitle"> <rdfs:domain rdf:resource="http://kasn.org/schema/core/#StandardDocument"/> <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/> </owl:DatatypeProperty>
statement	<owl:DatatypeProperty rdf:about="http://kasn.org/schema/core/dataproperty/#statement"> <rdfs:domain rdf:resource="http://kasn.org/schema/core/#Statement"/> <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/> </owl:DatatypeProperty>

V. CONCLUSION

The achievement standards linked data profile is a framework that supports the development of various teaching/learning support services based on an open approach of conversion, storage, and search with machine-readable expressions (RDF/OWL) with respect to the achievement standards and achievement levels of each elementary/middle/high school subject provided by educational institutions and organizations. This paper examined the linked data, on which interests have been focused recently, with the method of open data policy and introduces a method of producing linked data of teaching/learning achievement standards. The national education curriculum requires explicitly providing the standards that students must achieve for each curriculum component, going beyond a simple method of listing the curriculum components; planning a class and supporting the learning activities according to these standards; and determining the achievement levels through fair assessment. Therefore, basically, a teaching/learning support system implemented in the future has to be able to implement a service model based on the achievement standards of the national education curriculum. To this end, the achievement standards linked data profile should be continuously expanded and elaborated.

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