Matching Learners with Materials and Learning Experiences

Dagobert Soergel, Amy Miller

University at Buffalo, United States

Abstract

We propose a fine-grained multi-faceted metadata schema for precise, highly individualized matching of students with learning resources (materials and experiences) This match must consider (1) the student's present state of knowledge and their learning objectives (the student's place in a learning trajectory) and scaffolding requirements; (2) student strengths materials should draw on to support learning and student challenges materials should help the student meet; (3) the student's learning style; (4) the student's cultural and social background; (5) time and support resources available to the student; and more. We first draw on guidelines for materials selection ([x]. [y], [z]) and literature in the learning sciences to derive metadata requirements and then *consider two learning materials metadata standards and two learning material repositories – the formal metadata used and additional information available (and possibly amenable to automatic extraction) in the learning object description. We also discuss how one can get values for metadata elements through automatic extraction, crowdsourcing, and feedback from students and teachers using a learning object.*

Keywords: *Individualized instruction; learning materials selection; learning materials metadata*

1. Introduction

This paper contributes to making learning more efficient through better ways of selecting learning materials, of matching learning materials with learners, particularly to support highly individualized learning [1]. This is important because being successful in modern society requires ever more knowledge and thinking skills, but time for acquiring this knowledge and skills cannot be expanded indefinitely.

This brief paper is organized as follows. Section 2 gives some first insights into metadata requirements, drawing on guidelines for materials selection ([x]. [y], [z]) and literature in the learning sciences ([]) and our own thinking, complemented by a look at existing standards and learning materials repositories. Section 3 compares two standards ([x], [y] and metadata used in two repositories ([x], [y]) to each other and to the requirements. Section 4 presents some ideas on creating better metadata, and Section 5 concludes the paper.

Existing guidelines focus on selection of materials for classroom use and pay much less attention to individualized learning or to other contexts of learning, such as patient education. Existing standards and metadata practices are quite limited. The treatment of selection criteria and resulting metadata requirements is by necessity eclectic, giving a few examples from a vast space. But the paper points the way to a large research program resulting in a comprehensive knowledge base on criteria and processes for describing and assessing learning materials.

We use the term *learning materials* as a collective reference and the term *learning object* to refer to an individual document (or, in Dublin Core language, document-like object) that is intended to support learning and instruction. Other terms used include *instructional materials*, *learning unit*, *learning resource.*

2. Metadata Requirements for the Selection of Learning Materials

This section presents an illustrative multi-dimensional framework for specifying metadata requirements. Table 1 shows some principal dimensions, with emphasis on dimensions that are important but not commonly used. Table 2 shows sample values and gives comments for selected dimensions.

For this paper, the match between a learning object and a learner or a group of learners is fundamental. This match can occur at any of the levels specified under *Learning context*: a whole school system, a class, a small group (usually of students with similar characteristics), or an individual learner.

Metadata requirements can be extended for specific subjects, such as science [10] or type of material, such as oral history, specifically interviews with Holocaust survivors [11].

Table 1. Framework for specifying metadata requirements for the selection of learning materials illustrated with selected dimensions
(+ in at least one metadata schema, ± Sometimes mentioned in learning object description)

Content	Structure, organization, presentation, format	Audience, learning context, learner characteristics	Purpose, outcome, match
Inclusiveness +Subject . +Topical subject . +Geographical subject . +Temporal subject Relationship to lesson / instructional unit / broader curriculum Relevance to specific problems Prerequisites Position in a learning path +Alignment with SOL +Event World view	+Organization of learning object Instructional design +LearningObjectType +InteractivityType +Presentation complexity Reading level Reasoning words [12] Ways used to engage learners Uses examples Uses metaphors Diverse activities: Group and individual, hands-on, requires movement, longer investigations Expressive power Visual appeal Easy for teachers, students, and parents to use Complete set of instructions, materials, activities, assessments, and answers • Appropriate support for new teachers	+Learning context +Age +Grade level ±AbilityLevel, subdivided by area of ability +CompetencyLevel, subdivided by area of competency Knowledge, specified by specific areas and knowledge items Vocabulary knowledge +Learning style Disability	Each learner characteristic has a corresponding match criterion +Subject/topic learning objectives Attitude objectives Thinking skill objectives Empathy objectives Value objectives Learner engagement

Table 2. Examples and comments

Dimension	Examples and comments
Learning context	Even though this belongs under Audience, it is so fundamental to matching that we list it first. Sample values Whole school system or building Whole class lecture or activity Small group in a class (same topic, multiple groups, different learning object for each group) Group study, no teacher Individualized instruction by tutor Individual study, no teacher Home schooling

Inclusiveness	Inclusiveness means including the other – people who are often discriminated against because they are in one way or another different from the majority or dominant culture (many of these ways are mentioned in anti-discrimination laws). Inclusiveness should make the "other" recognized and fully included and should promote understanding of the other in members of the majority. Inclusiveness cuts across the top categories in the framework. It refers to, among others, • content covered, such as discrimination of all kinds in society • examples used (in all subjects, even word problems in mathematics) • characters in fiction assigned as reading • use of language
Relevance to specific problems the learner wants to solve	Patient education and precision medicine. For example, educational materials for educating a patient on ways to prevent or treat obesity through diet must take into account the genetic makeup and other medical conditions of the patient Speech therapy For example, materials to work with the patient on articulation. Even better if one can search for specific articulation problems, such as the letter *R.*
Event	National holidays, other memorial days, religious holidays. In a multinational classroom this can be individualized according to national origin of individual students
World view	Secular Religious (can subdivide by religion or denomination)
Organization of learning object **Instructional design**	Uses explicit knowledge organization Uses graphic organizers Starts with a story (one way to engage learner interest)
Uses reasoning words	Carefully chosen reasoning words in questions to students promote open-ended thinking / divergent thinking / inventiveness [12]
Ways used to engage learner	Relates to learner background - makes information relevant, thus promotes moving information to long-term memory Start with a story Learner can identify with characters in real or fictional story
Suitability for learners with specific disabilities	Suitable for visually handicapped learners Suitable for learners on the autism spectrum Suitable for dyscalculic learners
Learning style	Note: A number of studies report that matching learning materials with learners based on learning style has no effect on learning outcome. Given the difficulty of measuring learning outcomes and all the individual and situational factors that affect outcomes, a critical re-evaluation of these studies may be warranted. Also, should explore several aspects of learning style
Attitudinal objectives	Counteracts mathematics anxiety Attracts girls to STEM

3. Existing Learning Material Metadata

Existing metadata schemes emphasize physical properties, technical requirements, and access rights (all out of scope for this paper) and fairly obvious properties having to do with learning. Table 3 gives a small sample across the four standards mentioned in the introduction. IEEE standard 1484_12_1-2020 LOM specializes in obscure data element names and definitions that need reading three times to understand, if then. schema.org LearningResource is the most complete.

Table 3. Existing learning material metadata across four schemes. Some examples

Union list	schema.org LearningResource	IEEE LOM Standard	Teachers Pay Teachers	Am. Federation of Teachers
Subject				
. Topical subject	about	Keywords	Subject	Subject (broad) Topic (specific)
. Geographical subj.	spatialCoverage	General.Coverage		
. Temporal subject	temporalCoverage	General.Coverage		
+CompetencyLevel	competencyRequired			
Alignment with SOL	educationalAlignment	Classification.Purpose	Standards	Standards
Event				Event
LearningObjectType	learningResourceType	Educational.Learning ResourceType	Resource Type	Resource Type
+InteractivityType	interactivityType	Educational.InteractivityType		
Age range	typicalAgeRange	Educ.TypicalAgeRange		
Educational level	educationalLevel	Educational.Difficulty	Grade Levels	Grade
Ability level			In some descriptions	
Disability			In some descriptions	
LearningObjective	teaches			

4. Creating Better Metadata

Creating metadata by paid knowledgeable indexers is best but prohibitively expensive. This section presents a few approaches to efficient metadata creation that can be pursued.

Automated metadata creation through knowledge-based text processing. Text to be processed includes any descriptions and reviews available (including information in a syllabus) and written text in the learning object itself (including text on slides and speaker notes). Spoken text can be converted through speech recognition, and text in figures can be recovered through optical character recognition. Use automatic indexing and information extraction for fine-grained subject indexing. What concepts and propositions are treated in the text? What prerequisites do they imply? Determine reading level, including information on the vocabulary being used (How well does it match the vocabulary competence of the intended audience, down to an individual learner?). Detect definitions to see whether unfamiliar terms are defined. What vocabulary words to be learned does the learning object introduce? Do questions to learners include reasoning words that stimulate thinking. Does the learning object include examples and metaphors? If so, appropriate for what audience? Are there figures, diagrams, tables? How complex? Stylistic analysis: Quality of writing, slide density. Level of interactivity that can be seen from the text.

Crowdsourcing. Many learning materials repositories rely on a large number of contributors and solicit reviews from users. Develop a metadata schema and a controlled vocabulary (Sections 2 and 3 present ideas on how to do this) and ask learning object authors and reviewers to use it, making their contributions more useful. With proper guards of privacy, institute a process for collecting data on the outcomes of using a learning objects (including learner characteristics and other factors), then use machine learning to determine which learning objects support successful learning by whom. Of course

Learning materials repositories as research environments. Institute a process for researchers to recruit volunteer participants for studies of learners and their use of and success with learning materials.

5. Conclusions

Modern information system and knowledge organization techniques have great potential for improving learning through selection of the most appropriate materials for learning in the classroom and, even more importantly, for highly individualized learning. We have presented beginnings of a schema for learning material metadata that would help reach the potential of good selection, but we have also shown through examples that metadata prescribed in existing standards and/or in learning material repositories, while certainly useful and have improved access to learning materials, are far from sufficient. Finally, we have presented ideas how sufficient metadata could be created at reasonable cost so that the potential of optimal selection could be reached.

References

[1] McClaskey, Kathleen (2017). "Personalization and UDL: A perfect match." Educational Leadership. vol. 74(6).

[2] "Evaluation and Selection of Learning Resources: A Guide "(2008). Department of Education Prince Edward Island.

[3] Bugler, Dan, et al. (2017). “How Teachers Judge the Quality of Instructional Materials,” WestEd https://www.wested.org/wp-content/uploads/2017/03/resource-selecting-instructional-materials-brief-1-quality.pdf14.

[4] Rude, Carolyn (1974). “Evaluating and Selecting Instructional Materials for Specific Learners,” Iowa State Department of Public Instruction. http://publications.iowa.gov/id/eprint/23867

[5] Barker, Phil; Campbelll, Lorna (2010). "Metadata for learning materials: An overview of existing standards and current developments". Technology, Instruction, Cognition and Learning. 7 (3-4): 225-243.

[6] IEEE 1484.12.1-2020 - "IEEE Standard for Learning Object Metadata." https://standards.ieee.org/standard/1484_12_1-2020.html

[7] "LearningResource" schema.org. https://schema.org/LearningResource

[8] "Teaching Resources & Lesson Plans. Teachers Pay Teachers." https://www.teacherspayteachers.com/

[9] "American Federation of Teachers digital platform." https://sharemylesson.com

[10] "Guidelines for the Evaluation of Instructional Materials in Science" (2017). BSCS https://mcmprodaaas.s3.amazonaws.com/s3fs-public/BSCS_NGAL_2017.pdf?g.wcpSUoFAiYgCR0nFV8A_QOsEuuMY_l

[11] Newton Lawley, K., Soergel, D., & Huang, X. (2005). Relevance criteria used by teachers in selecting oral history materials. ASIST 2005: 421-448

[12] Boyd, Maureen; Kong, Yiren (2017). "Reasoning Words as Linguistic Features of Exploratory Talk: Classroom Use and What It Can Tell Us". Discourse Processes 54 (1): 62–81.