Learner Models: A Systematic Literature Research in Norms and Standards

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1 INTRODUCTION

Learners in higher education tend to become an increasingly heterogeneous group. Differences between learners exist in terms of, e.g., individual levels of knowledge and competences, varying learning styles, or individual preferences for (digital) media. Instructors face severe difficulties in paying proper attention to these individual differences in physical classes since individual coaching does not scale to larger groups of learners.

A potential solution for this dilemma lies in supplementary offerings of learning materials that are targeted to the individual needs of a learner in a specific situation. Yet, such supplementary offerings face some challenges since learners often do not know the best learning activity for them in a specific situation. This implies that mechanisms are needed to recommend meaningful next activities and materials. Consequently, such recommendations presuppose knowledge of properties of individual learners that would determine the usefulness of learning material in a specific situation. However, the required knowledge about the learner is not available, especially when initialising new (recommendation) systems (called *cold start problem*), so that the possibility of using learning analytics is very limited. Information systems often have the so-called cold start problem at the beginning (Bobadilla et al., 2012) – due to a general lack of users within the system (Schafer et al., 2007; Schein et al., 2002), the learner is new to the system and no data is yet available (Park & Chu, 2009; Park & Tuzhilin, 2008) or the learning element has been newly created and has not yet been used (Du Boucher-Ryan & Bridge, 2006; Rashid et al., 2002) – i.e. there is no or too little data available to be able to generate meaningful recommendations from it. In addition to the behavioural data of the individual, we believe that the structural characteristics – such as age, previous educational path, etc. – are also important in order to be able to create a digital image of the learner that is as comprehensive as possible (Bodily et al., 2018). This type of knowledge is usually captured in a so-called learner model or digital twin (Furini et al., 2022; Hlioui et al., 2016).

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Learner models have been discussed for quite some time, yet without consensus on which contents should be captured. This paper presents the results of a systematic analysis of standards and norms that deal with aspects of learner models in e-learning systems. With such an analysis, we want to identify requirements for structure and contents of learner models.

As it turns out, 16 standards and norms tend to be relevant. Yet, there is no single source that specifies the contents of a learner model in a comprehensive fashion since some of the sources are too specific, while others cover a variety of aspects in addition to those related to learner models.

In the following, the paper will clarify important terms and discuss related work, before section 3 details the employed research approach. Section 4 presents the results of the systematic literature research. Section 5 concludes the paper and gives an outlook to future work. A major effort will consist in combining the results of the analysis of standards and norms with results from a systematic literature analysis of scientific papers on learner models that we conduct in parallel to the work reported here. Findings of the latter analysis will be presented in a separate paper.

2 RESEARCH THREADS

2.1 Definition of Terms

There is no widely accepted definition of the term "*Learner Model*". Rather, discussions of this term are often controversial. Still, a consistent definition of the term is necessary as a basis for further work. As a first step, the two components of the term "*Learner Model*" will be considered separately before we return to the term in its entirety.

A **model** describes some aspects of a real system or subject relevant for the respective purpose as a conscious abstraction of its real counterpart. The most important characteristics of models are:

- Models do not describe the respective system or subject completely, but from a certain point of view while neglecting others;
- several models can exist for a system or subject in parallel;
- models exist at different levels of abstraction, ranging from a high-level view to a detailed representation;
- all relevant properties of the original must be adequately and completely mapped to properties of the model (*validation required*).

In our field of research, a model serves as a digital representation of students (*learners*), with the aim of providing individual learning support in a digital environment.

"Two things are crucial for an adaptive system to work: the existence of a means to adapt the task and the ability to detect the need for adaptation" (Johnson & Taatgen, 2005, p. 430). This ability to adapt is generally represented by so-called user models. Interpretations of the term **User Model** (*UM*) differ widely in the literature (Kay et al., 2022) and depend on the intended use, scope, domain and the way to collect information about the user (Hlioui et al., 2016). In general, a "user model is a representation of static and dynamic information about an individual that is utilized throughout the whole interaction process aiming to trigger a number of adaptation and personalization effects. […] [This user model] entails all the information which is considered important in order to adapt and personalize the user interface (content and navigation) and functionalities to the unique characteristics of a user. […] Depending on the domain and goals of the system, user models can include different kinds of characteristics about the users (e.g., interests, preferences, traits, etc.) or data with respect to their overall context of use (e.g., environment, time, interaction device type, etc.)" (Germanakos & Belk, 2016, p. 79).

Our research focusses on higher education where the general user model takes a specific shape as learner model. A **Learner Model** (*LM*) thus contains the individual characteristics and interaction data of a single learner, represents them explicitly in a machine-internal representation, and includes many different aspects, which ultimately depend on the purpose of the application. The terms *Student Model* or *Digital Twin*, which often appear in the literature, are synonyms of Learner Model in our setting, as all our learners are usually university students. The process of creating such a learner model is called *learner modelling* (Khenissi et al., 2015; Piao & Breslin, 2018).

2.2 Research Question & Field

Even though learner models are relevant for different disciplines, we explicitly focus here on computer science (*technical implementation*) and pedagogy (*teaching methodology*) and deliberately ignore other important sub-disciplines, such as the humanities for the time being. In doing so, we look at relevant norms and standards from different points of view from the perspective of computer science and pedagogy with the aim of answering the question: "***How can***

Learner Models look like and what are their structure and components?”. The selection of the models to be considered is guided by their (technical) feasibility, even if they are currently only described theoretically. Purely theoretical thought experiments without practical relevance and implementation possibilities will not be shortlisted.

2.3 Related Work

A widely recognized, well-founded learner model is still lacking, even though learner models are becoming increasingly important with the growing number of e-learning systems and the possibilities of computer-assisted learning. There is some work on defining learner models within different projects (Hlioui et al., 2016; Stiubiener et al., 2010) or for different purposes (Bodily et al., 2018; Bull & Kay, 2007). A systematic review of scientific literature that is conducted in parallel to the work reported here will provide a comprehensive overview of existing learner models. To the best of our knowledge, however, there is no systematic analysis of learner models based on standards yet.

3 RESEARCH DESIGN & METHODS

With the increase in digital teaching and learning opportunities, the desire for uniform standards in the field of e-learning is growing. The same applies to user models in digital ecosystems. To get an overview of related work on the topic of learner models, a systematic literature review (*SLR*) according to (Brereton et al., 2007; Kitchenham & Charters, 2007) is useful. The process of a systematic literature review warrants a balanced and objective summary and overview of the topic of the research question, which is (theoretically) reproducible and transparent at any time. Well-defined requirements form the basis for the five-stage review process: *(manual) search*, *plausibility check*, *selection based on filter*, *check references of each relevant item* and *total result*. The planning phase of the systematic literature review consists of the following general steps.

3.1 Relevant Research Sources

Apparently, there is no single point of contact for norms and standards, but a wide range of different providers, from government agencies to consortia of various commercial companies. Seven popular electronic database sources [RS1 – RS6] were selected as the most relevant for the area of standards in e-learning for adaptive teaching and learning. An important criterion in the selection of data sources was to obtain published works – standards, norms, drafts or even technical reports – from the searched area that fulfill basic quality criteria (e.g. peer-reviewed) and are accessible to the public (to a certain extent). If there are results that cannot be assigned to any of the above-mentioned publishers, these are summarized under various and shown separately in the results. The aim was to identify and evaluate existing standards in the area of learner models. For this purpose, current standards, but also discontinued ones and drafts were used for selection.

Table 1: Overview of Relevant Sources.

Ref.	Provider
RS1	World Standards Cooperation (WSC) *www.worldstandardscooperation.org*
RS1a	International Organization for Standardization (ISO) *www.iso.org*
RS1b	International Electrotechnical Commission (IEC) *www.iec.ch*
~~**RS1c**~~	~~International Telecommunication Union (ITU)~~ ~~*www.itu.int*~~
RS2	IEEE Standards Association (IEEE SA) *standards.ieee.org*
RS3	1EdTech Consortium *www.1edtech.org*
RS4	World Wide Web Consortium (W3C) www.w3.org
RS5	Internet Engineering Task Force (IETF) *www.ietf.org*
RS6	Organization for the Advancement of Structured Information Standards (OASIS) *www.oasis-open.org*

This table of providers is supplemented with a loose collection of other standardised specifications, for example from ministries/governments or other organisations that have written guidelines on this topic. These are grouped under the term “*various*”. The spectrum of standards publishers ranges from international standards publishers to professional associations and international industry consortia.

As an alliance, the *World Standards Cooperation* (*WSC*) is a globally active association of the voluntary, consensus-based system of standardisation. Of the three member organisations, the two international standardisation organisations *International Organization for Standardization* (*ISO*) and *International Electrotechnical Commission* (*IEC*) are relevant, which jointly develop international standards in the fields of electrics and electronics. Of the most important professional organisations in this case, the *Association for Computing Machinery* (*ACM*) and the *Institute of Electrical and Electronics Engineers* (*IEEE*), the latter develops global consensus-based standards with the *IEEE Standards Association* (*IEEE SA*), including in the area of learning technology and information technology. Numerous international industry partners are also joining forces to form larger consortia in order to better represent their interests. During the research phase, four consortia emerged as an important opportunity. The *1EdTech Consortium* (formerly the *IMS Global Learning Consortium*) aims to develop open standards for the e-learning sector. In recent years, numerous *IMS* specifications have become global de facto standards in the field of e-learning, the issues surrounding networked "Internet technologies", such as the *WWW*, are highly relevant. This is why the two consortia *World Wide Web Consortium* (*W3C*) and the *Internet Engineering Task Force* (*IETF*) are an important starting point in the search for relevant standards in this area. Less present organisations, such as the *Organisation for the Advancement of Structured Information Standards* (*OASIS*), are also represented in this area and should also be considered.

3.2 Search Strategy

In order to obtain all the desired results and thus to be able to create as comprehensive an overview of the domain as possible, it is important in the first step to create a list of synonyms, abbreviations and alternative spellings for the selected search terms. Synonym dictionaries, spelling dictionaries and, lastly, feedback from our experts were used for this step. Table 2 shows the search terms used, including various spellings and abbreviations. This list does not claim to be complete, but should cover a large part of the search terms. In the second step, the different variations are meaningfully linked with each other using Boolean operators.

The organisations that strive for standards were searched with a slightly modified search strategy. For this purpose, the search query above was simplified and divided into several sequential search queries. If a search was not possible or not feasible in a meaningful way, all available standards were manually sifted through including reading and assessing the summary in interaction with the title. Subsequently, the importance for the topics of eLearning in connection with Learner Models was checked manually via referenced standards. In addition, all standards in the eLearning field were searched by hand so that no important references were left unnoticed.

Table 2: Search Query Components.

Search Term	Variations	Category
Learner Model	"Learner Model"	
	"Student Model"	*Synonym*
	"Pupil Model"	*Synonym*
	"digital Twin"	*Synonym*
	"educational Data Model"	*Synonym*
	"User Model"	*Synonym*
	<Synonym> AND "learning"	*Alternative*
	<Synonym> AND "education"	*Alternative*
Learner Modeling	"Learner Modeling"	
	"Learner Modelling"	*Alternative*

The search terms used for searching the data sources described above linked with boolean operators (query) is:

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("Learner Model" OR "Student Model"
OR <Synonym>) AND <Alternative>
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In addition, a plausibility check was conducted in the next stage. For this purpose, external sources were searched for possible results of the publishers, which were removed by the publisher due to date of publishing or validity or other reasons and no longer made available to the public. The aim was to obtain as comprehensive a view as possible of approaches that had already been discarded. The results found are then assigned to the respective publishers.

3.3 Selection Criteria and Filters

To limit the aggregation process, various selection criteria were defined in order to be able to refine the existing results in a more targeted manner. The criteria and various filters are listed and briefly explained below. Basic filters were

Language of Choice
Only publications in German or English were selected from the above database resources.

Quality Criteria
Only publications that were subject to quality control prior to publication were selected. This criterion is particularly important for drafts and preliminary standards, as these do not necessarily have to be subject to standardised quality guidelines. This means that at least a small group of people worked together and reviewed each other and additionally a well-known organization or an association of well-known

commercial companies is behind a standardization and its concept.

Filter
The standard scientific criteria – such as title, keywords, conclusion – cannot be transferred 1:1 for the evaluation of standards and norms. After the manual search, a manual plausibility check was carried out. The results found were then filtered according to

- **Abstract**
  The abstract should already indicate if the content is appropriate for the research question.
- **Research Field/ Discipline**
  The discipline of the result must be in the field of e-learning (*computer science and teaching methodology*).
- **Full-text**
  After this pre-selection, the remaining standards were read fully and evaluated.

After successful filtering, the relevant results were analysed for their respective references and links. The relevant results from the references were added to the result set and ran through the same process described above. In the case of dubious decisions by the individual filters, it was assumed that the current filter was fulfilled, as this “critical” work is then sorted out by other subsequent filters at a later point in time. The title was not used as a filter criterion, as experience had shown that it provided little information about the content of the relevant standard. The filters are run sequentially in the order just described. Preferably, these criteria should be reviewed by multiple researchers to weed out irrelevant papers. The filters just described can also be deliberately overridden individually in very few exceptional cases, for example if a model found is referenced by numerous papers (thus constituting seminal work). Such exceptions are marked separately at first mention. Furthermore, after the full text analysis, all references of each relevant article and their authors are checked to see if there are other important publications outside the search scope that should definitely be included in the results.

3.4 Selection of Extracted Data

The data to be extracted from the analysed publications depend primarily on the respective research question. The extracted data – i.e. the characteristics of the models - should be as objective as possible, as these serve as a basis for comparison between the different models and their features. At the outset, there should be an awareness that standards cannot be easily compared. Therefore, the evaluation should be a purely qualitative benchmarking of existing standards rather than a direct comparison between them. Table 3 shows the most important general attributes of standards. These can be divided into metadata – such as name, publication date or current status – and content data, in this case the standard’s purpose or its central ideas. As an option specific attributes may be recorded in addition to the general attributes.

Table 3: Overview of extracted data categories.

Category		**Attribute**	***Example values for attributes***
General Attributes	**Metadata**	Name of the Standard	*Standard for Awesomeness*
		Publication Date	*01/01/2000*
		Last Update	*05/30/2023*
		Standardisation organisation/ Publisher	*Standards Association*
		Types of Standard	*Technical Specifications (TS)*
		Discipline	*Computer Science*
		Status/ Revision process	*Active Standard*
		Version	*v2*
		Superseded Standards	---
		Linked Standards	---
	Content Data	Central ideas / Target	*- to standardise a learner model that is as generalised as possible* *- basis for the specialisation of own LMs*
Specific Attributes			---

4 SYSTEMATIC LITERATURE REVIEW

4.1 Evaluation of Results

Figure 1 shows the individual (interim) results after applying the methodology from chapter 3.

From a total of 869 (manually) searched possible results, only 16 relevant results remain after the process of systematic literature research. The continuum of the scope of the standards and norms to be analysed in detail ranges from around 30 pages of technical reports to several hundred pages of international standards. These relevant results are compared and discussed in the following chapter.

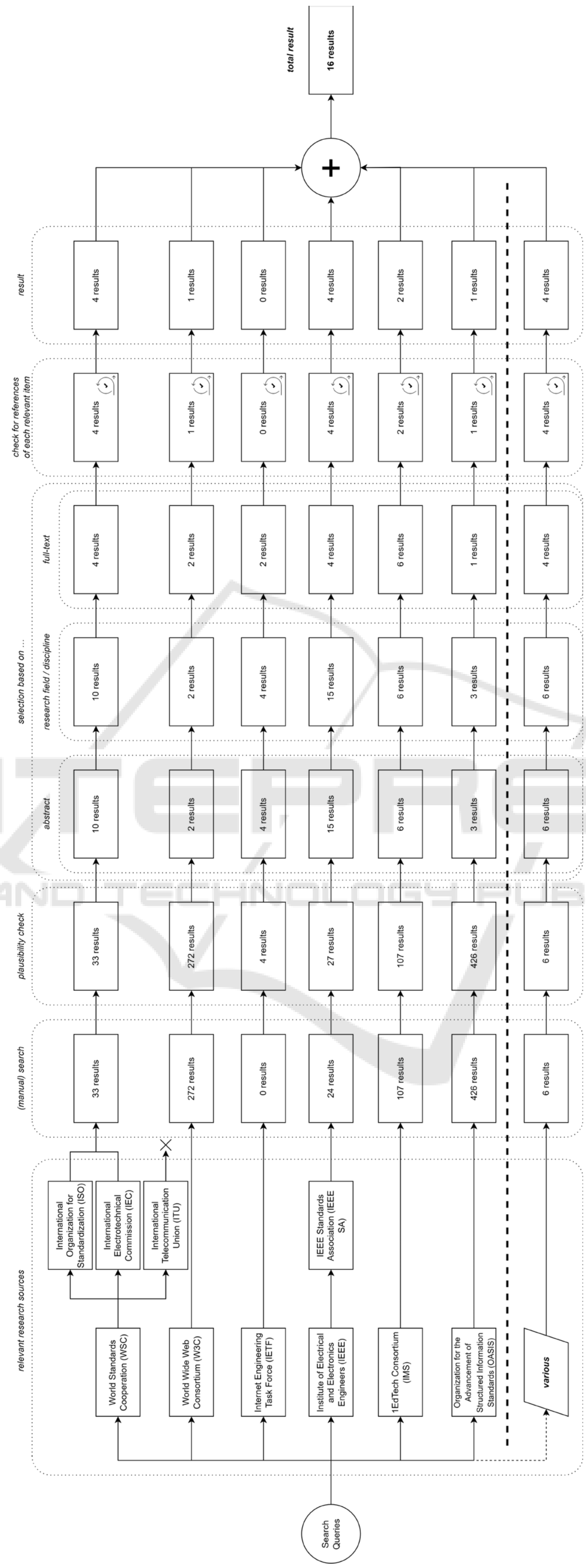

Figure 1: Overview of the (interim) results of SLR.

4.2 Overview of Results

Before the remaining standards are compared with each other, they are briefly presented individually below.

ISO/ IEC 19479:2019 (ISO/IEC 19479, 2019)
Model for recording and exchanging attested learning achievement information in a formal learning environment to express the level, content and type of qualification. In addition, it defines refinements to the learner mobility achievement award (*LMAI*) model for representing the digital diploma supplement, which is defined in terms of a conceptual model and a domain model.

ISO/ IEC 19788-9:2015 (ISO/IEC 19788-9, 2015)
Specification for metadata elements and their attributes for the description of learning resources. Providing a standards-based approach to the identification and specification of the metadata elements required to describe a learning resource.

ISO/ IEC TR 20748-1:2016 (ISO/IEC TR 20748-1, 2016)
Specifies a reference model that identifies the diverse IT system requirements of learning analytics interoperability. The reference model identifies relevant terminology, user requirements (use cases), workflow and a reference architecture for learning analytics, assessments, accessibility preferences and data flow and data exchange.

ISO/ IEC TS 29140:2021 (ISO/IEC 29140, 2021)
Provides a learner information model specific to mobile learning to enable learning, education and training environments to reflect the specific needs of mobile participants. The use of a learner information model for mobile technology in learning, education and training (mobile learning) is also addressed.

W3C Working Group Note: Making Content Usable for People with Cognitive and Learning Disabilities (W3C Working Group, 2021)
Planning, creation and process of accessible applications usable by people with cognitive and learning disabilities.

IEEE P1484.2 (IEEE P1484.2, 1997)
Specify the syntax and semantics of a 'Learner Model', which will characterize a learner and his or her knowledge/abilities. These elements to be represented in multiple levels of granularity, from a coarse overview, down to the smallest conceivable sub-element and allow also different views of the Learner Model (learner, teacher, parent, school, employer, etc.) and substantially address issues of privacy and security. The Learner Model will provide more personalized and effective instruction.

IEEE P9274.4.1 (IEEE P9274.4.1, 2022)
Describes the technical implementation of *xAPI*.

IEEE 9274.1.1-2023 (IEEE 9274.1.1, 2023)
Standardizes the data model format and communication protocol for learning experience data allowing vendors to build interoperable solutions and to take advantage of many products that support the *xAPI*.

IEEE P2997 (IEEE P2997, 2021)
Defines the Enterprise Learner Record (*ELR*) data model for the various data objects. The ELR data model preserves data ownership and integrity by providing indications to where raw learner data is stored and by providing the ability to track: - the learner's path through different organizations - the variety of learning experiences - demonstrated competencies - conferred credentials - employment history. Additionally, it defines the transfer methods and application programming interface (*API*) for communicating learner records between services that adhere to the specification.

1EdTech Learner Information Package Specification (1EdTech, 2001)
Addresses the interoperability of internet-based Learner Information systems with other systems that support the Internet learning environment.

1EdTech Student Learning Data Model (1EdTech, 2020)
Provides a complete view of a digital (*1EdTech*) ecosystem interconnected with real-time data. This includes the following sub-areas: User and Organization, Enrollment and Attendance, Pathways to Competency, Instructional Resources, Assignment and Assessment, Learning Activities, Learner Record.

OASIS Specification for JSON Abstract Data Notation (*JADN*) (OASIS JADN, 2021)
A formal description technique for expressing the information needs of communicating applications, and rules for generating data structures to satisfy those needs.

Common Education Data Standards (Common Education Data Standards, 2022)
Data standards and a shared vocabulary for education data.

Dynamics 365 Education Accelerator (Microsoft Education, 2023a)
A proprietary and commercial technical realisation of an education data model component.

Open Education Analytics (OEA) (Microsoft Education, 2023b)

An open source-based reference architecture to develop modern data intelligence capabilities.

Ed-Fi Unifying Data Model (UDM) (Ed-Fi, 2023)
An educational data tool suite (unifying data model, data exchange framework, application framework, and sample dashboard source code) that enables vital academic information on K-12 students to be consolidated from the different data systems of school districts so that educators can start addressing the individual needs of each student from day one, and can measure progress and refine action plans throughout the school year. Elements are aligned to *CEDS*.

4.3 Discussion of Results

The remaining 16 publications were compared with the aim of forming a basis for a learner model to be developed. To this end, various aspects of the learner model were examined in more detail. Basically, the standards already differ in terms of the purpose and the reason for their existence. These range from exchange options for learner data (system requirements for interoperability) (ISO/IEC 19479, 2019) (ISO/IEC TR 20748-1, 2016) and their implementation (IEEE P9274.4.1, 2022), through the specification of learning resources (ISO/IEC 19788-9, 2015), for example for people with cognitive and learning disabilities (W3C Working Group, 2021), to a complete comprehensive digital ecosystem in which the learner is part of it (1EdTech, 2020) (Ed-Fi, 2023). The target groups of the various standards are also broadly diversified and range from individual learners (ISO/IEC 29140, 2021) (1EdTech, 2001) to entire groups involved in the teaching and learning process, for example learners, teachers, parents and also the administrative educational institution (IEEE P2997, 2021) (Common Education Data Standards, 2022). The type and origin of the standard also differs from, for example, industry standards (Microsoft Education, 2023a) (Microsoft Education, 2023b) to active standards from consortia (IEEE 9274.1.1, 2023) (OASIS JADN, 2021) or their predevelopment: Drafts (IEEE P1484.2, 1997).

Finally, of the remaining standards, three can be highlighted that are explicit learner models: (IEEE P1484.2, 1997) (1EdTech, 2001) and (ISO/IEC 29140, 2021). (ISO/IEC 29140, 2021) describes a mobile learner model and its specific attributes for learning, such as device, connectivity, or location.

The (1EdTech, 2001) deals with the interoperability of Internet-based information systems for learners with other systems. For this purpose, the learner is specified and stored in a learner information server and made available for other applications. The learner specification is based on a data model that describes the characteristics of a learner that are necessary for recording and managing the learner's progress, goals, achievements and learning experience.

The draft (IEEE P1484.2, 1997) attempted to specify the syntax and semantics of a learner model that characterizes a learner and their knowledge/skills and was first drafted in 1997 with the aim of centralizing Public and Private Information for Learners (therefore also known as *PAPI Learner*). The learner information is divided into six categories:

- *PAPI Learning Staff* (demographic data)
- *PAPI Learner Relations* (relationships with other learners)
- *PAPI Learner Safety* (enrollment information)
- *PAPI Leaner Performance* (future goals)
- *PAPI Learner Preference* (preferences)
- *PAPI Leaner Portfolio* (previous experience)

The early date of first publication is a possible indicator that could point to this, but not a sufficient condition for the conclusion that the topic of learner models was already very important at the end of the 1990s. In the early 2000s, the draft was transferred from *IEEE SA* (*IEEE/LTSC*) to *ISO* (*ISO/IEC JTC1 SC36*) in collaboration with *IMS* (now *1EdTech*), but soon disappeared from the scene. The research could not uncover any obvious reason why work on the draft was discontinued.

Research into possible norms and standards in the area of learner models has shown that there are very few approaches in this field and that these are either specialized (ISO/IEC 29140, 2021) or very complex and more than just learner models (1EdTech, 2001) or have not yet been pursued further (IEEE P1484.2, 1997). However, these can form a very good basis for developing your own learner models, such as (Common Education Data Standards, 2022) or (Ed-Fi, 2023) and can be extended according to one's own needs.

For reasons of brevity, not all details can be presented here. However, in order to ensure the reproducibility of the SLR and the transparency of the methodology, all information on the SLR is made available to the public online (Böck, 2023).

5 CONCLUSION & FUTURE WORK

Heterogeneity of learners in higher education is continuously increasing due to, e.g., individual levels of knowledge and competences, varying learning styles, or individual preferences for (digital) media. Offering learning elements with an optimal fit to the learner's specific needs presupposes detailed knowledge of the learner's characteristics, captured in a learner model. A systematic literature research on existing norms and standards in the area of learner models revealed 16 relevant publications, 3 of which present their version of a learner model. Still, these models are not comprehensive or overloaded with additional content that does not contribute to characterizing learners. Nevertheless, these models provide some indications what should be included in a learner model and how such a model might be organized.

In parallel to the work reported here, we work on a systematic literature research and analysis of scientific publications on learner models. Next steps will include matching the results of both analyses, standards on the one hand and scientific literature on the other, in order to derive requirements on appropriate contents of such models.

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