Smart Learning Environments

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Standards for smart education – towards a development framework

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Abstract

Smart learning environments (SLEs) utilize a range of digital technologies in supporting learning, education and training; they also provide a prominent signpost for how future learning environments might be shaped. Thus, while innovation proceeds, SLEs are receiving growing attention from the research community, outputs from which are discussed in this paper. Likewise, this broad application of educational digital technologies is also the remit of standardization in an ISO committee, also discussed in this paper. These two communities share a common interest in, conceptualizing this emerging domain with the aim to identifying direction to further development. In doing so, terminology issues arise along with key questions such as, *'how is smart learning different from traditional learning?'* Presenting a bigger challenge is the question, *'how can standardization work be best scoped in today's innovation-rich, networked, cloud-based and data-driven learning environments?'* In responding, this conceptual paper seeks to identify candidate constructs and approaches that might lead to stable, coherent and exhaustive understanding of smart learning environments, thereby providing standards development for learning, education and training a needed direction. Based on reviews of pioneering work within smart learning, smart education and smart learning environments we highlight two models, a cognitive smart learning model and a smartness level model. These models are evaluated against current standardization challenges in the field of learning, education and training to form the basis for a development platform for new standards in this area.

Keywords: Smart learning, Smart learning environments, Standardization, Reference model, Development framework

Introduction

The word 'smart' is now routinely used by the educational research community forming new terminology like Smart Education, Smart University, Smart Learning, Smart Classroom, Smart Learning Environment, etc. (Uskov et al., 2017; Roumen & Kovatcheva, 2017). We could see this as an expression of the dynamic nature of the contemporary educational domain, which is now also often characterised in terms of transformation (Liu et al., 2017; Bell, 2017; Walker et al., 2016: Tuomi, 2013; Baker & Wiseman, 2008). Fast changing domains need to be conceptualized in order to be understood and optimised for their stakeholders (Bell, 2017). This is one role of educational research now articulated in several journals and books and explored in this paper. In the domain of digital technology, however, innovation has its own dynamics and is not necessarily driven by research – often it is all about being 'first to market'. Thus, from a different though potentially more stabilizing position, another community of professionals try to harness the insights of research together with innovations at the frontier of change to document stable points of reference, so the domain can evolve in a progressive and sustainable way. This is the standards community, the group that does IT standardization for learning, education and training (ITLET) within the International Organization for Standardization (ISO).

In this paper, we examine outputs from the smart education research community and the ITLET standards community to identify how evolving conceptual frameworks could inform specification work stabilizing the core terminology (e.g., as in smart technologies) in order to promote innovation. Our examination is based on the understanding that the former community is struggling to map the new terrain and create adequate conceptual frameworks, while the latter community is struggling to discard old frameworks, make sense of the new dynamics, and propose new frameworks. This research is the first of its kind trying to align the outputs of smart education research and ITLET standardization.

For some of the leading exponents of the research community focused on smart learning a key objective is to optimise the operations of smart learning environments thereby ensuring a virtuous loop of innovation. Roumen and Kovatcheva (2017) point to an Educational Innovation Grid framework consisting of four quadrants made by the two axes digital technologies (existing providers vs new entrants), and learner ownership (formal learning vs informal learning). This presents four kinds of change: improving schools, supplementing schools, reinventing schools, and new paradigms (Fig. 1). The research community address all these changes and has a particular focus on how they are integrated, learning taking place in both informal and formal settings, using both new and well-established technologies.

It is significant in this context to emphasise the research community is not a homogenous group governed by requirements to achieve consensus but is ultimately driven by innovation. Standardization work, on the other hand, typically involves conceptual, technical, and political activities that together are focused on achieving consensus among a group of stakeholders. The outcome – a standard – is essentially just a document that represents a stable reference point and sometimes includes detailed

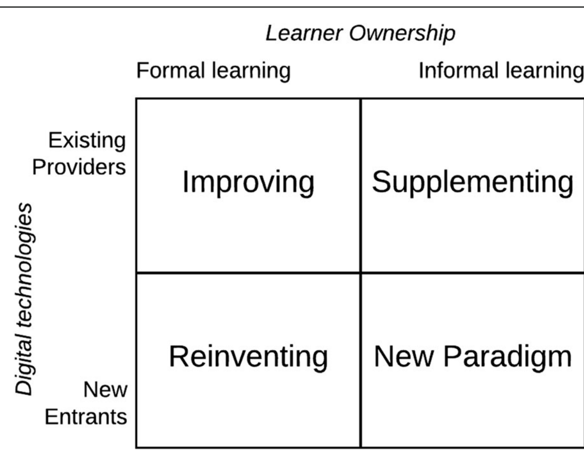

Fig. 1 The education innovation grid (Adapted from Roumen & Kovatcheva, 2017)

technical specifications. Standardization can also be conceived as a design activity that seeks to identify and harmonize common elements from disparate inputs to support interoperability and a level playing field for further innovation and adoption of technologies. In education, standardization has played a pivotal role in promoting the principle of systems interoperability in deployment and use of learning technologies allowing the sector to move in *smarter* direction. We live in an era of change, and it is therefore a challenge to align standardization with the needs of the domain. In the technology enhanced learning domain, both the standardization community and the domain experts for some time have asked themselves what the new frameworks for development would look like.

The following discussion offers a critical examination of the *smart* in smart education, smart learning and smart learning environments (SLE) in two steps. First, we analyze a selection of papers in two key journals. Based on this analysis one paper is chosen to inform a SLE model that is discussed against requirements from the field of ITLET standardization (see section 1.1 below). This discussion results in some preliminary conclusions about veracity of the model in guiding standardization work. Next, we review the SLC to identify further conceptualizations of SLE. New perspectives are found, and this informs an additional model, which may add guidance to standardization work. This new model is discussed against a backdrop of ITLET standards framework. In the conclusion, we offer ideas for further development of a framework that could inform the development of SLEs and SLE standards.

The following discussion elaborates in further detail on the context of ITLET standards development and some prominent articles published by the research community.

The standardization context

In this paper, we highlight Sub-Committee 36 (hereafter, SC36) of ISO/IEC Joint Technical Committee 1 as a backdrop for discussing how frameworks for Smart Learning Environments (SLE) developed by the research community could inform standards work. SC36 was initially formed in 1999 with scope to produce IT standards for Learning, Education, and Training (LET). Within SC36 the acronym ITLET (IT for Learning, Education, and Training) is commonly used. Since its inception, SC36 has produced a range of standards, some which have reflected market needs and some which do not. In 2017, the chair stated "[SC36] realize(s) that the role of technology in learning, education and training has changed, and continue(s) to change – we in SC36 need to be more agile in adapting our work processes and organization to reflect this" (Overby, 2017).

In line with all formal ISO/IEC standards development, SC36 can choose from three standardization outputs to guide its work – a Technical Report (TR), Technical Specification (TS), or full International Standard (IS). In all cases, such documents detail some degree of consensus from stakeholders. Within such outputs, it is also typical that other standards and industry specifications are normatively referenced or customised as application profiles specific for the ITLET domain. Because the development of a full IS can take many years, however, developing a TR or TS is often a practical first milestone and, given the rapid rate of innovation with digital technologies, there is an added challenge for SC36 to align its work practically.

In terms of process, all standardization activity is typically initiated by a New Work Item Proposal (NWIP) and if there is sufficient stakeholder buy-in this transitions to a formal New Work Item (NWI) – in which a clear scope statement and market need is articulated. In recent years, the trend within SC36 has been to initiate Study Groups prior to the development of an NWI so that the scoping work can be as focused as possible. Experience within SC36 has been that if scope statements are in any way ambiguous then many problems arise in progressing the work. Such Study Groups typically produce a short report which then informs the development of a Technical Report. In some cases, SC36 can also choose to adopt or adapt industry specifications as international standards that might have been developed by Liaison Organizations. Because the ITLET market is growing rapidly and innovations are constantly taking place it makes a lot of sense for SC36 to first do due diligence in identifying what industry specifications or standards might be useful rather than perform a quasi-academic research in determining market needs.

Well-defined vocabularies (terms, their associated definitions, and normative references) provide the foundation on which most standardization activities proceed – and ontologies that demand precise terminology are often important components of the digital infrastructure. This is essential for IT because terminology is what describes a domain of activity and conceptual coherence is essential. Of course, definitions of the same term vary depending on the context of application and this can sometimes be confusing to those outside the standardization process. In standards development, however, terms are defined to be fit for purpose and the definition of 'smart' as in a smart person will likely be quite different to the definition of 'smart' as in a smart phone – and, it makes no sense to appropriate a term that has high utility within English and to try and define it for all contexts. Therefore, this is where we also commence our discussion on Smart Learning Environments.

The smart learning environment research context

In a similar way that SC36 has grappled with aligning its program and organizational structure with evolving technological development, there has been a parallel development in conceptualization resulting in establishing *smart learning* as a new field of research. The International Association of Smart Learning Environments (IASLE) has defined smart learning as: "an emerging area alongside other related emerging areas such as smart technology, smart teaching, smart education, smart-e-learning, smart classrooms, smart universities, smart society. The challenging exploitation of smart environments for learning together with new technologies and approaches such as ubiquitous learning and mobile learning could be termed smart learning" (IASLE, n.d.).

Smart, however, is a term that has long been associated with computers (Zuboff, 2015, 1988; Bell, 2017; Kallinikos, 2010); it also has high utility across many discourses and therefore can be problematic when defining it. Thus, IASLE explains that the "adjective 'smart' in smart learning involves some similar characteristics to the ones attributed to a person that is regarded as being 'smart'" (IASLE, n.d.). But, to proceed with any technical design activity based on the concept of smart learning there is a need to do further theoretical groundwork. In the marketplace, where smartphones have been such a success, *smart* is arguably just a term that has managed to get traction more than *intelligent* – but it certainly shares similar semantics. Perhaps the problem for *intelligent* is that it has been part of artificial intelligence (AI) for decades and for many of us that conjures up other meanings.

IASLE also points to three journals for research outputs on smart learning, *Interactive Technology and Smart Education Journal* (first volume 2004); *Smart Learning Environments* (first volume 2014); and the *International Journal of Smart Technology and Learning* (first volume 2016). While the first and oldest journal seems to have focussed more on the interactive technology and less on building theories on how these technologies are smart, the last two journals have from the very beginning tried to define the new overarching concept of smartness related to learning. For this paper, we first focus on research published in these two journals that aim at establishing a theoretical foundation for SLEs.

Methodology

In seeking to bridge the research and standardization discourses our work is focused on conceptualisations, models, and frameworks. Prior to a New Work Item being proposed within the ISO standardization process it is typically the case for a study group to convene and to likewise undertake such work while also addressing issues such as market need. In the domain of information technology, conceptual modelling needs to be tested prior to the next stages of validation which typically involve the specification of data models and reference implementations. To produce adequate conceptual models work must first proceed on specifying the conceptual domain through identifying well-formed constructs. Likewise, academic research typically proceeds from specifying a well-formed research question. Thus, for this paper, our research question is: *What candidate constructs from contemporary research into smart learning environments might lead to a stable and coherent depiction of smart learning environments that can be progressed within the processes of international standardization?*

From the key journals identified above, we have selected five papers for analysis based on the following questions: *what papers in the inaugural issues of the two journals have the ambition to lay the conceptual groundwork for further research on SLE?* and, *what papers bring new theoretical grounding for understanding the 'smart' in SLE*?

Defining smart

To build an understanding of the characteristics that define smart learning IASLE used the vernacular definition of smart – as in a person being smart. This follows the line of argument pursued by one of the early advocates of smart education in China, Professor Zhu Zhiting of East China Normal University, who defined *smart* in a keynote presentation to an international audience as the opposite of stupid: "If you don't quite agree [..] with the definition of smarter education, then let's first find evidences of stupid education…" (Zhu, 2014). It is easy to find examples of 'stupid education'; Professor Zhu mentions "refusing to tailor teaching approaches accordingly and denying individuality", and "solely emphasizing book-based knowledge while neglecting development of practical abilities" (Zhu, 2014). Elsewhere, smart is defined through examples of contemporary technology trends introduced by any of the players in the international market, such as IBM in its report Education for a Smarter Planet (2009). It is also inferred in national policy documents such as *Keep it Clever* by Universities Australia (2014) and an "ecology of smart learning" in South Korea consisting of self-paced e-learning, virtual classrooms, mobile learning, collaboration based learning, social learning, simulation based learning, game-based learning, etc. (Lee, 2011). This leads to a preliminary definition of smart education proposed by Zhu and Bin (2012): "the essence of smarter education is to create intelligent environments by using smart technologies, so that smart pedagogies can be facilitated as to provide personalized learning services and empower learners to develop talents of wisdom that have better value orientation, higher thinking quality, and stronger conduct ability."

In Zhu, Yu, and Riezebos, 2016 concluded "there is no clear and unified definition of smart learning so far". Besides the natural explanation that a new and multidisciplinary research field needs time to develop consensus, we suggest that a well-formed definition of smart learning requires more conceptual rigor. This is not easy for terms that already have high usage and utility in everyday conversation. Thus, in earlier work, we argued that to achieve a good scope statement one must focus on defining what is in scope, not on describing what is out of scope (Hoel & Mason, 2012). By defining A as not being B one is bound to establish a fuzzy concept of A with unclear boundaries. We have observed this line of argument in some of the attempts to define smart learning. Therefore, in exploring whether a solid theoretical base for smart learning can be discerned for the next generation of ITLET standardization activities, we examine some of the initial attempts to define the field.

While the foregoing provides some context for a growing discourse we propose that standardization processes can also provide useful guidance in how to proceed with defining terminology. For example, *ISO 704:2009 Terminology Work – Principles and methods* has been developed for this specific purpose (ISO, 2009). A key principle here is to identify the constraints of the domain in which a term is used to designate something and to specify any distinguishing characteristics. Thus, within the domain of ITLET, terms describe systems and their components. Moreover, as *ISO 704:2009* demonstrates, terms and definitions are themselves entities within concept systems in which terms and definitions are associated with concepts that have relations to other concepts. The most formal expression of such a concept system is an ontology. Thus, in reviewing the emerging discourse on smart learning, our methodology has been to check to what extent the terminology shows such characteristics. It is our expectation that for this field to mature such an ontology will need to be developed.

Defining smart learning

The journal *Smart Learning Environments* was launched in 2014 with the aim "to help various stakeholders of smart learning environments better understand each other's role in the overall process of education and how they may support each other". In the opening article, Spector (2014) focuses on "conceptualizing the emerging field of smart learning environments" pointing to "three foundation areas that provide meaningful and convergent input for the design, development and deployment of smart learning environments: epistemology, psychology and technology". A smart learning environment, then "is one that is effective, efficient and engaging" (p. 2). To create a framework for a SLE, Spector extracts characteristics from the three foundational perspectives and classifies them according to whether they are necessary, highly desirable, or likely (see Fig. 2).

Hwang (2014) identified context-awareness; adaptiveness; and ability to adapt user interface, subject content, and report learning status as the key criteria of a SLE. Figure 3 describes the modules of Hwang's SLE system.

Zhu et al., 2016 define ten key features of a SLE: location-awareness, context-awareness, social awareness, interoperability, seamless connection, adaptability, ubiquitousness, whole record (of learning path data), natural (multimodal) interaction, and high engagement.

Zhu et al. (2016) also introduce a 'smart education framework', identifying core elements for successful learning in a digital world (Fig. 4). The core elements identified are consistent with the Community of Inquiry (CoI) model initially outlined by Dewey and Pierce and refined for teaching in the digital era by Garrison: teacher presence, learner presence, and technology presence (Garrison et al., 2010). For Zhu, Sun, and Riezebos (2016), teacher presence is manifest in terms of instructional design, facilitating and directing instructions, and providing technology support. Technology presence provides connectivity, ubiquitous access, and personalized services; while learner presence is characterized by autonomous and collaborative learner roles and efficient technology use.

Koper (2014) defines SLEs as "physical environments that are enriched with digital, context-aware and adaptive devices, to promote better and faster learning" (p.1). According to Koper, an SLE as a technical system consists of one or more digital devices added to physical locations of the learner (p. 4). The digital devices are aware of the learners' location, context and culture; and they add learning functions to these elements, such as provision of augmented information, assessment, remote collaboration, feedforward, feedback, etc. Furthermore, the digital device will monitor the progress of learners and provide appropriate information to relevant stakeholders.

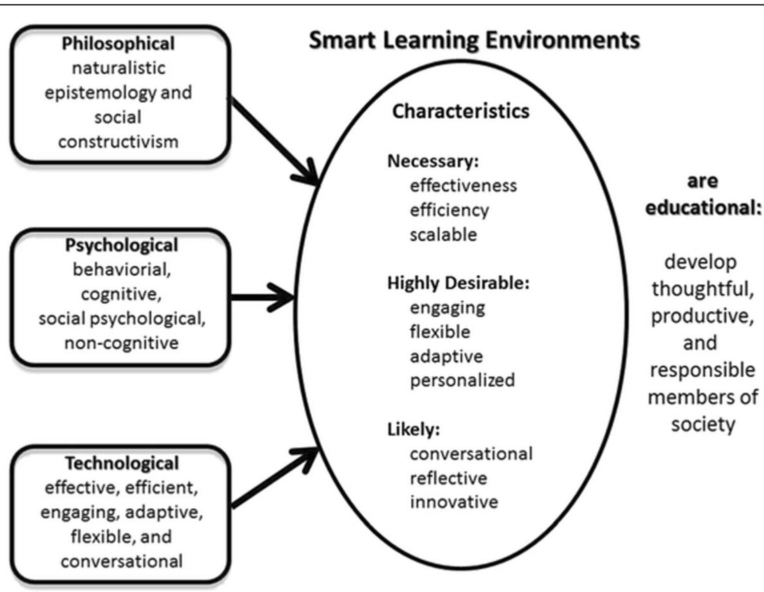

Fig. 2 Spector's preliminary framework for SLE (Spector, 2014)

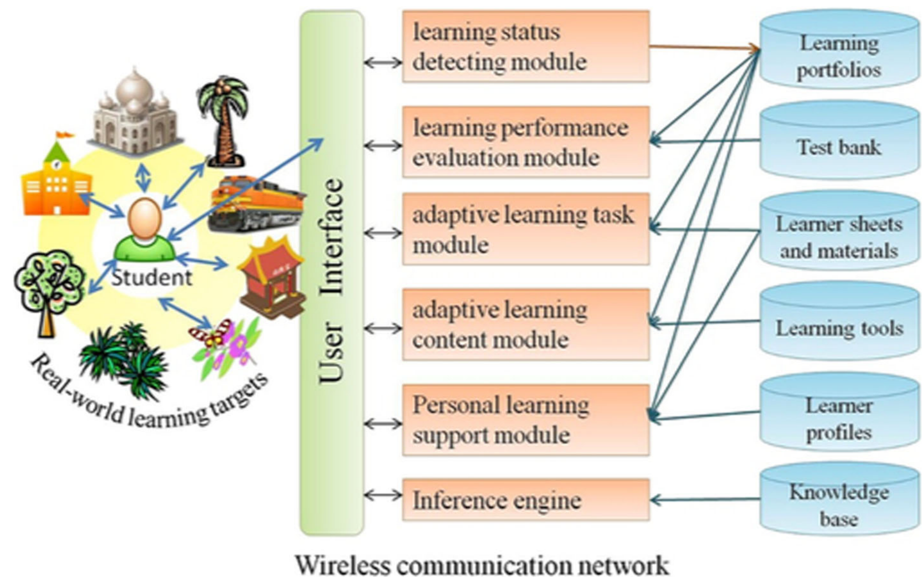

Fig. 3 Hwang's framework of a SLE (Hwang, 2014)

To identify the requirements for the distinguishing feature of an SLE – that it provides *better and faster learning* – Koper introduces the concept of a Human Learning Interface (HLI), a "set of interaction mechanisms that humans expose to the outside world, and that can be used to control, stimulate and facilitate their learning processes". What HLIs there are to be considered in a SLE are, according to Koper, depending on what learning theories one subscribes to. Koper also delves into behaviorism, the cognitive sciences, and social psychology and discerns five HLIs that together provide a coherent set of levers to influence the quality and speed of learning (Fig. 5). This representation also shares some commonality with the famous four-dimensional SECI spiral of knowledge conversion developed by

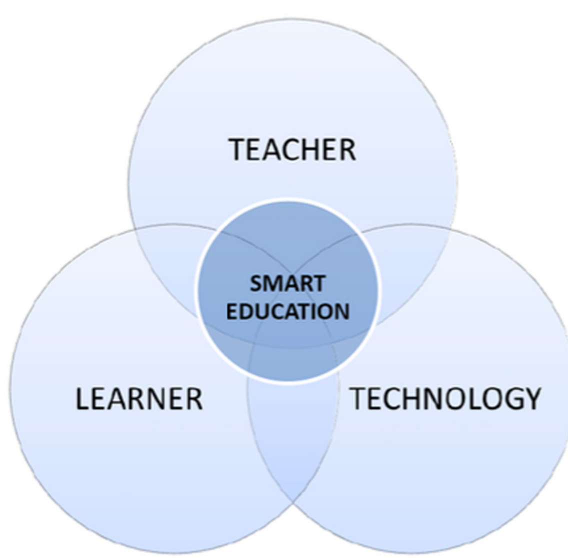

Fig. 4 Zhu et al.'s smart education framework (Zhu et al., 2016)

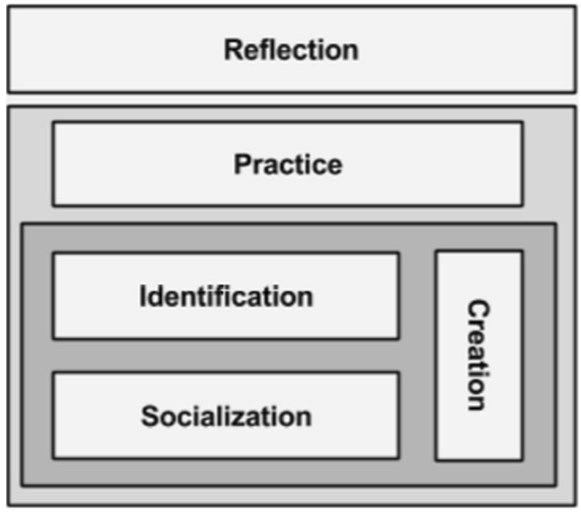

Fig. 5 Five human learning interfaces identified by Koper (2014)

Nonaka (1990), the founder of modern knowledge management – where SECI stands for socialization, externalization, combination, and internalization. In Koper's model, *identification* represents the new situations and events in the world; *socialization* represents the settings, the social norms, values, customs, etc.; *creation* represents the activities to produce outputs; *practice* represents knowledge and actions that are repeated to prepare for high performance in future situations; and *reflection* represents creating representations of representations transforming initial representations and behaviors evident from practice.

An extended definition of Koper's SLE, with both the technical and pedagogical characteristics covered, is therefore the "physical environments that are improved to promote better and faster learning by enriching the environment with context-aware and adaptive digital devices that, together with the existing constituents of the physical environment, provide the situations, events, interventions and observations needed to stimulate a person to learn to know and deal with situations (identification), to socialize with the group, to create artifacts, and to practice and reflect" (Koper, 2014, p. 14).

Finding a theoretical grounding of SLEs

Of the papers discussed, only Spector (2014) and Koper (2014) attempt to ground their conceptualization of a SLE in theoretical fields that underpin learning theories; however, their approaches are substantially different. For Spector, there is a serendipitous and associative way of searching for a theoretical grounding in the question: *How do these perspectives inform the development of a conceptual framework for smart learning environments?* Perhaps there are a few characteristics from these foundational perspectives that can be extracted and used as a preliminary set of indicators of the smartness of a learning environment (Spector, 2014, p. 7).

In Spector's framework (Fig. 2) each new scan through philosophical, psychological and technological perspectives will lead to new characteristics that are classified related to their desirability according to metrics that are highly contextual and temporal (e.g., efficiency, innovative). The model is without boundaries, as there are no limits to the number of iterations in search for characteristics.

In contrast, Koper has scrutinized learning theories with the aim to develop a comprehensive, but limited set of human learning interfaces that can play a role in an implementable SLE. Three core interfaces must be supported to initiate a learning activity: identification, socialization and creation. For better and faster learning to happen two meta interfaces must be supported: practice and reflection.

The contributions of Hwang (2014), and Zhu et al. (2016) have more in common with Spector's approach than with Koper's. Hwang lists characteristics of a dynamic system (context-awareness, adaptiveness, personalized), and keep his model open to any new technology trend to appear. Zhu, Sun, and Riezebos (2016) also list desirable characteristics of learning technologies, stopping at ten, but leaving the framework open to include any new approach in fashion. In the latter, a framework is abstracted to a level where everything involving a teacher, a learner and technology is considered being part of SLEs.

In conclusion, this brief comparison of these conceptual papers demonstrates a lack of work grounding ideas of intelligent and self-regulation technical systems in learning theories that could indicate which interfaces to influence to achieve the aims of better and faster learning. Arguably, the work of Koper (2014) is an exception. His five HLIs are derived from cognitive sciences, and they constitute a firm base for interfacing whatever new mode of technology supported activity to be found with the learning operations of the individual. In the following, we model Koper's conditions for effective smart learning environments, to see if this contribution could be used as a basis for further design work in the context of ITLET standardization.

Constructing a SLE reference model – The Core

To validate the concepts defined in Koper (2014) against requirements derived from ITLET standardization use cases we have constructed a SLE core reference model described in Fig. 6.

The elements of model can be described as follows: A Learning Instance, the key element to be observed in a SLE system, is a unit of learning that has activated the main activities represented in learning, which are accessible through HLIs. The Learning Instance is instantiated through input from the Physical Environment, and through other contextual influence factors, e.g., a teacher defines a task, set up an event, define goals, etc.; and the teacher make interventions that presuppose the use of digital devices. For learning to happen, the learner must identify the situation (task, learning goals, schedule, etc.); the learner must interact with other learners, directly or indirectly; the learner must create outputs to externalize learning achievements; and the learner must perform meta activities through Practicing and Reflection. SLE system sensors monitor each activity of a learning instance; the observations are fed back to a Context-awareness & Adaptiveness engine that adjusts the input factors for the next learning instantiation.

Testing the SLE reference model can be done in two steps. First, the model must withstand requirements coming from other SLE conceptualizations. Second, the model must prove itself useful for the main purpose of this research that is related to further

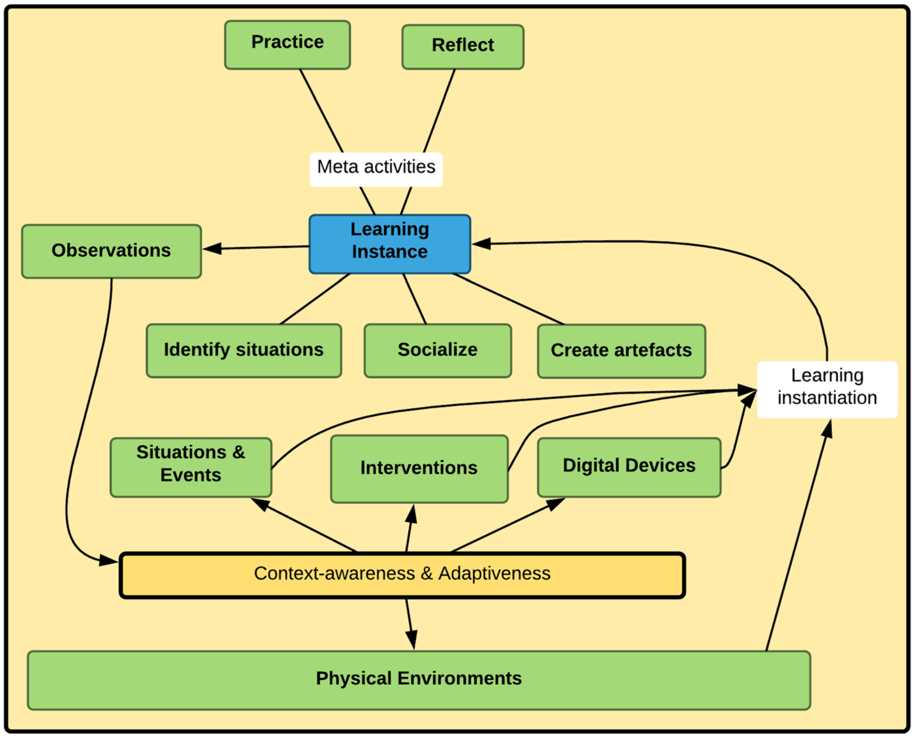

Fig. 6 SLE core reference model (based on Koper, 2014)

standards development: Will the model work as a framework for ITLET standards development? To reach a conclusive answer this will need testing. Additionally, 'reference implementations' can support the standardization process in contexts where innovation in technology is fast moving.

Testing against smart learning theories

We have characterized a number of conceptualizations of SLE as open and associative, while the model we have defined, based on Koper's (2014) work, is proposed to be more complete. We have wanted to develop a model that can integrate *new* smart innovations without having to introduce new system elements. To test the completeness of the model we contrast it with the framework of smart learning introduced in a recent book on smart learning in smart cities by Liu et al. (2017). Will the four types of support technologies for smart learning identified in their framework easily be integrated in the SLE model?

Figure 7 describes the smart learning framework of Liu et al. (2017). The model positions the learner in the centre, and consists of four levels (learning experience, support technologies, learning scenarios, and basic principles of teaching and learning).

Four support technologies for smart learning are identified (p. 38). Of type 1, *awareness and adaptive technologies*, artificial intelligence, sensors, and auto deduction are mentioned with applications that identify type of learning situation, provide diagnosis of learners' problems, personalized learning resources, social matching, and suggestions about learning activities. In the SLE reference model (Fig. 6), these support technologies

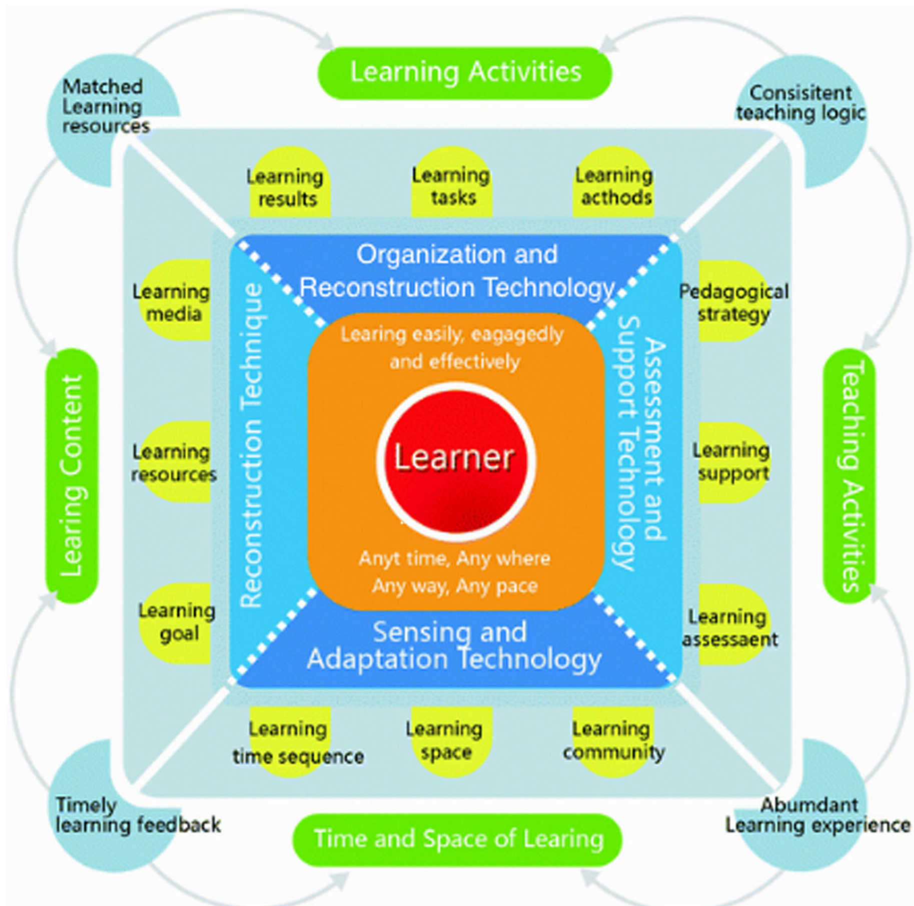

Fig. 7 Framework of smart learning (Liu et al., 2017)

will be part of Digital Devices; Observations will register data from sensors logging Learning Instance activities; and the Context-awareness & Adaptiveness engine will provide the services described and set up Situations & Events, design Interactions, etc. The SLE reference model accommodates the first type of support technology requirements well; however, we observe that there is a need to specify more in detail the reasoning engines that are part of the adaptive system.

Within this type of support technology, Liu et al. (2017) also list environment perception technologies, like RFID, video monitoring, etc. These are covered by the Physical Environments in the SLE reference model.

Type 2 is *assessment and support technologies*, i.e., teaching assessment technologies (association rules, data mining) and learning support technologies (augmented reality, 3D printing, rich media, learning terminal). Also, these technologies are accommodated by the SLE reference model, following the same pattern as for Type 1 technologies.

Type 3 is *tracking and analytic technologies*, of which Liu et al. (2017) identified dynamic tracking technologies like motion capture, emotion calculation, eye-movement tracking; and learning analytics technologies (Classroom teaching effect analysis, interactive text analysis, text mining, video, audio and system log analysis). These technologies could also be fitted in the SLE reference model. However, we see that the model could gain more explorative strengths if the reference framework could be extended with information models detailing data flows between sensors and analytical systems.

Type 4 is *organization and reconstruction technologies,* which Liu et al. (2017) describe as learning object and semantic web. These are content management technologies that are mainly covered by the Situations & Events element of the SLE reference model.

In conclusion, we see that the technology requirements for smart learning identified by Liu et al. (2017) do not break the SLE reference model based on Koper's work (2014). When technological aspects of smart learning are identified, it is the dynamic aspects of the model related to reasoning capabilities and feedback to system components that are valued. However, the pedagogical insights that are modeled in the different learning activities described in the model, and which are an important part of the SLE reference model, are not so much requested when contrasted with technological aspects of the Liu et al. smart learning framework. This might point to a potential weakness of the model for the use in a ITLET standardization framework. Even if a model does not break when tested against new requirements, it does not imply that the model is able to drive new development, e.g., in ITLET standardization. We will come back to this question after we have tested the model against requirements coming out of scoping activities in the standards community we use as a case in this paper.

Testing the SLE model against SC36 requirements

A challenge for SC36 is how to bring order to ad hoc study groups: augmented reality and virtual reality (AR&VR); smart learning environments and smart classrooms; digital badges; MOOCs; blockchain (electronic distributed ledger technologies; collaborative learning communication with social media; privacy and data protection for LET; etc.

The challenge for SC36 is twofold:

1. How to fit new work items into an existing organizational structure; or,
2. How to specify a domain framework that can produce the required new work items, and at the same time, support effective organization of work?

Bringing the SLE reference model (Fig. 6) into the picture, again we see that the themes listed above will fit in the model; however, a lot of specifications need to take place that are not explicated in the general SLE model. For example:

- AR&VR: These technologies typically extend both the cognitive and experiential domain with dedicated digital devices or application. Because AR and VR extend the scope of learning experience, however, questions arise as to what learner model is adequate for the learning session, etc. These issues are only implied in the SLE reference model.
- Digital badges: The Context-awareness & Adaptiveness engine will have access to assessment history and competency framework: these entities are not described in the model.
- Blockchain: This class of technologies is not covered in the model, other than as part of Observations.

- Privacy & data protection: These issues are not covered by the model; however, the human learning interface elements provide conceptual support for discussion of these issues.

The above discussion has identified technologies that the SLE model must accommodate. To generalize this, we need to ask, *is the model adequate in identifying new work items for standardization?*

One advantage of the model is its grounding in pedagogical theories with the definition of HLIs that are used to set up a learning instance. The five artifacts that are part of a learning instance could be used both for exploring potential standardization challenges, and for validation of existing projects. The reasoning behind the latter proposal is that all systems in a SLE must address one or more HLI to make learning happen. The model distinguishes between running a learning instance and setting up a learning instance. This might give inspiration to interesting standards projects.

The SLE model makes a distinction between physical and digital/virtual environments. This might lead to exploration of metrics for physical environments, project ideas that we have seen resonate with some Chinese interests (project proposal for defining standards for smart classrooms).

Otherwise, we note that the dynamic aspects of the model are represented as a simple feedback loop driven by Observations and managed by Context-awareness and Adaptiveness engines. This would need further specifications to be able to drive development of new standards projects.

In conclusion, the SLE reference model has some qualities as a reference framework for standards development. It could serve as a core model for how a learning instance is set up. However, in order to drive standards development contextual aspects of learning should be included in a SLE framework, i.e., aspects that captures the social-cultural perspective of learning (Engestrom, 2007), and how learning instances are configured in in time, locale, organization, etc. This is the focus of the next part of constructing a SLE reference model in this paper.

Constructing the SLE context model

Conceptual work in smart learning has been complemented with laboratory work setting up and testing smart classroom solutions. In USA, Uskov and colleagues have set up a smart classroom lab at Bradley University to test out different components of next generation smart classroom systems (Uskov et al., 2015; Uskov et al., 2015; Uskov et al., 2017).

Inspired by a presentation by Derzko (2007), Uskov et al. (2015) developed an intelligence level ontology to classify different smart systems. In Table 1 we have used this ontology to analyze different pedagogical activities, different technologies, and different standardization challenges that follow from the different smartness levels of SLE.

We see that the more advanced the SLE systems are, the more difficult it is to identify pedagogical practices, examples of technologies used and acknowledged standardization challenges. One explanation for this observation is that developing new technologies for learning and new practices is work-in-progress. We would compare this to the turn experienced by the field of Artificial Intelligence some years ago when they came out of the *AI winter* through a combination of processing power and use of

Table 1 Smartness level of Smart Learning Environments with activities, technologies etc. (Adapted from Uskov et al., 2015)

SLE levels	Smart Classroom Activities	Technologies involved	Standardization challenges
Adapt Ability to modify physical or behavioral characteristics to fit the environment or better survive in it.	• Communicate (local & remote) • Share content • View content in a preferred language • Initiate session with voice/facial/gesture commands • Ask questions • Present (local & remote) • Discuss • Annotate	• Web technologies • Session-based analytics • Personal digital devices • VR and AR systems • Presentation technologies (Smartboards, etc) • Social media • Sensors (air, temperature, number of persons, participation roles, ….)	• Setting up a SLE meeting quality criteria defined in Smart Classroom standards • Data governance • Privacy • Security • Systems interoperability
Sense Ability to identify, recognize, understand and/or become aware of phenomenon, event, object, impact, etc.	• Automatic adjustment of classroom environment (lights, AC, temperature, humidity, etc.) • Real-time collection of student feedback from diverse contexts • Monitoring student activity • Process real-time classroom data • Deliver custom support and scaffolding for special needs students • Support agent-based systems • Interact with smart systems • Connect multi-location students	• Triggers actions, defined in assorted models (learner, school, teacher, Smart Classroom, etc.) • Big Data • Multiple interfaces and channels keyboard, screen, voice, agent, eye movements, gestures	• Data collection and storage • Data governance • Privacy • Security
Infer Ability to make logical conclusion(s) on the basis of raw data, processed information, observations, evidence, assumptions, rules and logic reasoning.	• Recognize every individual • Process real-time classroom data • Process incomplete classroom datasets • Discuss presented learning content and assignments with remote students in real-time and using preferred language by each student	• Simple rule-based process engines • More complex inference engines • Natural language processors	• Pedagogical designs • Student learner models • Student activity data • Specifying competence
Learn Ability to acquire new or modify existing knowledge, experience, behavior to improve performance, effectiveness, skills, etc.	• Ability to suggest changes to the system • Real-time skills assessment • Real-time knowledge assessment • Accommodate and enact multiple intelligences	• Artificial Intelligence • Machine Learning • Deep Learning	• Validating competence • e-assessment • Learning Design

Table 1 Smartness level of Smart Learning Environments with activities, technologies etc. (Adapted from Uskov et al., 2015) *(Continued)*

SLE levels	Smart Classroom Activities	Technologies involved	Standardization challenges
Anticipate Ability of thinking or reasoning to predict what is going to happen or what to do next.		• Predictive engine (predictive analytics)	
Self-organize Ability of a system to change its internal structure (components), self-regenerate and self-sustain in purposeful (non-random) manner under appropriate conditions but without an external agent/entity.		• All above, with a strong AI component.	

big data. The point was not to mimic human intelligence but to mine the intelligence that was buried in the data to make the machine learn how to solve certain tasks. Our claim is that we are in a similar situation regarding the utilization of SLEs.

In Fig. 8 we describe the driving forces of smartness in SLE and the corresponding smartness levels. Systems that can adapt, sense and infer what is going on within a learning scenario may also be based on real-time human intelligence as well as that captured in the form of metadata ontologies, learner models, learning designs, etc. However, when the systems start to learn and to predict actions without any human management, and then self-organize and act as an independent agent in a learning scenario, the system is prone to be based on machine intelligence and driven by big data.

The model in Fig. 8 complements the SLE core model we developed. While the latter model describes how learning is initiated, the new model describes how the learning environments – the learning context – is set up and what affordances are to be expected.

With these two models as tools we will now turn to the challenges of the standards community in SC36 to come up with a strategy for creating new work items that could make the new SLEs more interoperable. This is the focus of the next section in this paper.

Iterations of standardization

The relentless development of new learning technologies and new pedagogical practices has led to conceptualization of techno-pedagogical frameworks, such as TPACK (Koehler & Mishra, 2009; Ferguson et al., 2017). Technically speaking, however, SLEs are part of a wider context of architectural development in the ITLET domain. For more than two decades there has been numerous initiatives aimed at defining or abstracting frameworks in which all relevant learning technology systems are modelled. A successful further development of the SLE will require a good grasp of the context – but, what are the pivotal elements in the different architectures; and even more importantly, what

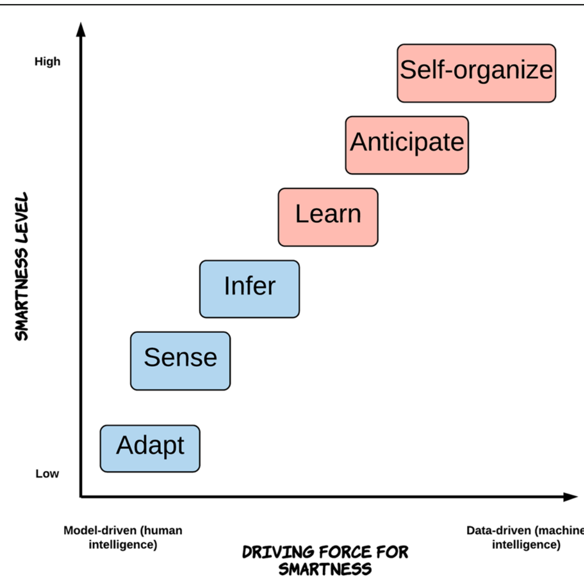

Fig. 8 Driving forces for different smartness levels in SLE (Based on Uskov et al., 2015)

are the pedagogical principles that are supported by each framework? This latter question will likely prove more challenging because 'smartness' is not exclusively a 'systems' feature; moreover, when pedagogy is a consideration then the technical work on learning design that has been proceeding since early in the millennium is likewise an important consideration (IMS GLC, 2003b).

In the following, we highlight some prominent initiatives that have made an impact on the ITLET standards community since the turn of the century.

IEEE learning technology systems architecture (LTSA)

The 2003 IEEE Learning Technology Systems Architecture (LTSA) (Fig. 9) represents the first purpose-built learning technology standard (IEEE, 2003). The standard has now been deprecated as it is no longer an adequate representation of the complex systems that are now used in ITLET. Nonetheless, as a stable reference point, it served its purpose and it is a concise rendering of the thinking at the time. What can we learn from this? Modelling the ITLET domain is an ongoing challenge in which new complexity is introduced with each new innovation in technology.

Thus, when defining the LTSA, IEEE defined the purpose of developing system architectures in general:

> [it] is to create high-level frameworks for understanding certain kinds of systems, their subsystems, and their interactions with related systems, i.e., more than one architecture is possible.
>
> An architecture is not a blueprint for designing a single system, but a framework for designing a range of systems over time, and for the analysis and comparison of these systems, i.e., an architecture is used for analysis and communication.
>
> By revealing the shared components of different systems at the right level of generality, an architecture promotes the design and implementation of components and subsystems that are reusable, cost-effective and adaptable, i.e., abstract, high-level interoperability interfaces and services are identified. (IEEE, 2003).

At the turn of the century, e-learning was still largely conceived as delivery of learning resources to a learner supported by a coach, with the aim of being evaluated; however, by this time it was also evident that for education *communications* is as essential

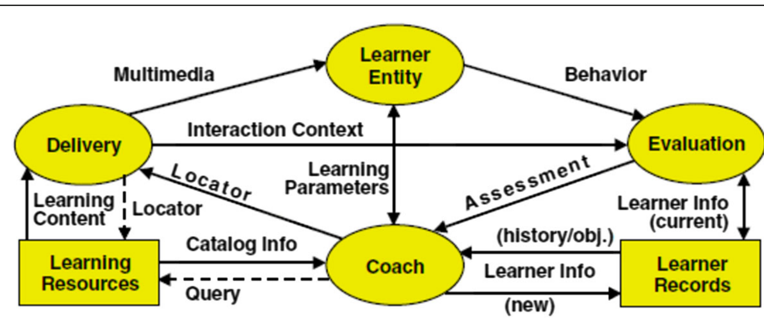

Fig. 9 LTSA system components (IEEE, 2003)

as *information* and the acronym ICT (information and communications technology) soon became commonplace. The importance of interaction and collaboration in the ITLET domain can also be seen in the emergence of sub-fields such as Computer Supported Collaborative Learning (CSCL).

IMS abstract framework

In the same year as the IEEE LTSA was published the IMS Global Learning Consortium (IMS GLC) also published its version of an Abstract Framework depicting the bigger picture of the technical specifications environment (IMS, 2003a). It is also of interest here that in the early years of its existence the IMS GLC branded its mission as "defining the internet architecture for learning" (Rada, 2001; Mason, 1999).

The framework (Fig. 10) defined four layers, an application layer; an application services layer; a common services layer; and an infrastructure layer.

As the IMS Abstract Framework is more abstract than LTSA, it is not that obvious what pedagogical requirements that are built into the framework. When a framework is too abstract, the threat is that it is passing above the head of the developers that should use it, which might have been the fate of this IMS initiative.

Oki

Shortly after the Massachusetts Institute of Technology (MIT) announced its bold Open Courseware initiative to the world, making its courses and programs freely accessible for scrutiny it also initiated the Open Knowledge Initiative (OKI) was also launched (MIT, 2002; Thorne et al., 2002). This project signalled a move towards a service-oriented approach for defining ITLET architectures, developing Open Service Interface Definitions (OSIDs) as programmatic interface specifications describing services. These interfaces were to achieve interoperability among applications across a varied base of underlying and changing technologies. Given the subsequent revolution in cloud services that rendered many enterprise architectures redundant, OKI can be now seen as a bellwether of change. It is unfortunate however, that MIT has not maintained its archive on its website associated with this initiative – also signalling that innovation in digital infrastructure is itself fragile and subject to disappearance. It is worth noting here, however, the scope of OKI also reached beyond the learning domain by explicitly acknowledging knowledge as much as learning. At that time, there was a rich emergent

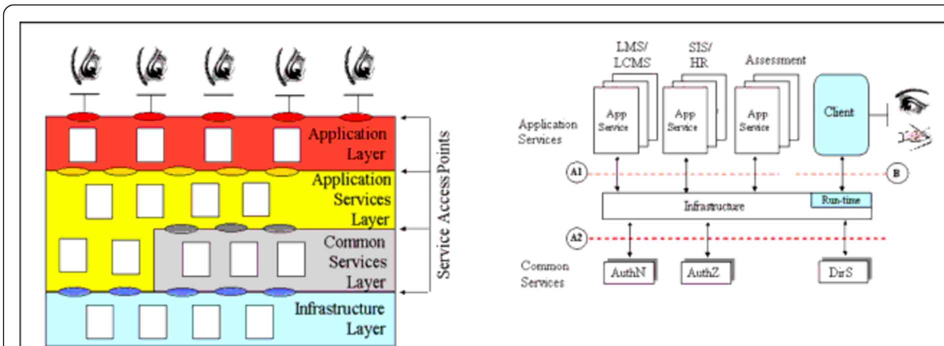

Fig. 10 IMS abstract framework (IMS, 2003a)

discourse that articulated the notion of shared services between knowledge-based systems and learning (Mason et al., 2003).

JISC E-learning framework

When service-oriented architectures became popular around 2005, the UK's Joint Information Systems Council (JISC) an ICT support agency for universities developed a service-oriented view of e-learning (Fig. 11). Sorting services in three categories: simple user agents, learning domain services, and common services, JISC developed a framework to "enhance learning by creating an open programming environment that supports sharing and pedagogical experimentation" (JISC, n.d.). This framework became the forerunner to an international collaboration in 2006–2007 known as the *e-Framework for Education and Research* and sponsored by government agencies in the UK, Australia, New Zealand, and The Netherlands. This framework proved useful as a reference within *ISO/IEC/TS 20013:2015 – A reference framework of ePortfolio information* published by SC36 as a Technical Specification in 2015.

ADL – The Total learning architecture

Fifteen years after IEEE started developing general architectural frameworks for e-learning and Advanced Distributed Learning (ADL), the US Department of Defense program that developed the Sharable Content Object Reference Model (SCORM) (ADL, 2004), embarked on new work focused on developing a "total learning architecture" (TLA) (ADL, 2016). While SCORM is arguably the most implemented ITLET standard in the world, and continues to serve a purpose in some contexts, ADL has identified further standards development that aligns more with the cloud-services and data-rich contemporary environment. SCORM was architected to specify the runtime requirements of maintaining sessions for the single-learner undertaking self-paced learning within an enterprise environment. In other words, it was very specific. In recent years ADL has developed xAPI (the eXperience API), which can be understood as an architecture that places an individual's experience, data outputs and requirements as the centrepiece as distinct from the content in SCORM. xAPI specifies an interface allowing different systems to share data tracking all kinds of learning activities. While xAPI is positioned well to accommodate much of the innovation in the learning

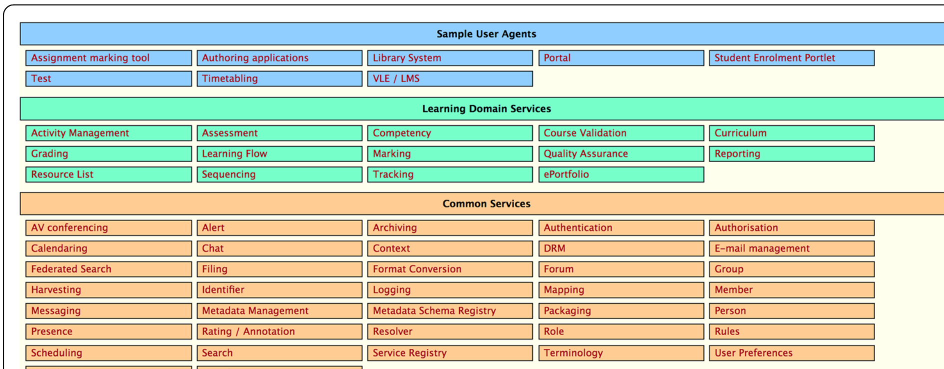

Fig. 11 The JISC E-Learning framework

analytics space it should also be understood as serving a specific purpose and is only an activity stream format. Thus, ADL has also been progressing work on the Total Learning Architecture (TLA), depicted in Fig. 12 as an organic ecosystem.

The TLA is the development initiative that comes closest to the ideas of a smart learning environment as described in the papers referenced above outlining the ideas of smart learning.

In Table 2 we have classified the above high-level standardization frameworks according to criteria used in the SLE models.

In reviewing these various abstract frameworks and architectures, five important themes can be identified:

1. A progression from a focus on modelling systems in which content was the primary component toward ecosystems that facilitate interaction and activities in which the learner is now the centrepiece.
2. Activity data from learners and other entities (instructors and platforms) is what drives the interworking of modules, systems and processes.
3. Standards and specifications development has shifted emphasis from big picture descriptions to targeted solutions for specific requirements. Broad frameworks are still needed, but what standards activities cycle between rendering abstract frameworks that represent key components of an ecosystem to specifying IT requirements of a specific component or group of services.
4. Application Programming Interfaces (APIs) are the points of integration or interoperability, where the service innovation is driven to the periphery relying on stable conduits of information through well-defined APIs.
5. Architectural models must deal with new complexities and can only realistically be dealt with when decomposed into autonomous modular subsystems or services.

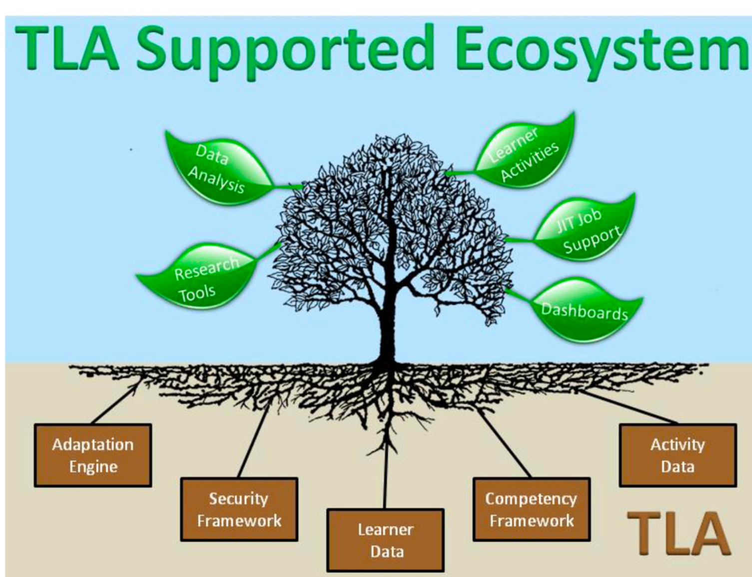

Fig. 12 Total Learning architecture (ADL, 2016)

Table 2 How development of standard frameworks is positioned in relation to SLE

Standards frameworks	Level of smartness	Data-driven?	Pedagogical model
LTSA	Pre SLE model	No	Content-driven
IMS	Service layer model anticipating adaptive systems	No	N/A
OKI	Service-oriented interfaces - a precondition for adaptive systems	No	Knowledge system view
JISC	Service-oriented	No, based on predefined metadata models	Heterogeneous pedagogies afforded by the tools made available
ADL-TLA	Self-organizing	Yes	Heterogeneous

Conclusions and further development

In this paper, our concern has been to connect two discourses: research into smart learning and digital technology standardization. The primary motivation for doing so has been to identify the common aspects and core constructs that might form the basis of a meta-framework, thereby adding value to both discourses. Our analysis to date indicates that pursuing this represents a logical next frontier for international ITLET standardization. The most promising candidate constructs for this purpose can be drawn from the work Koper (2014) and Uskov et al. (2015). We believe we have provided the basis for the synthesis required to progress standardization of a smart learning framework.

Our analysis also reveals numerous questions that require further investigation if such an endeavour is to prove fruitful. The following list is indicative:

- What sub-systems can be identified and defined as both self-contained and interoperable within a SLE?
- What lessons can we draw from reviewing the abstract modelling of earlier standards and specification development associated with ITLET?
- In what ways might digital infrastructure development (inclusive of specifications and standards development) undertaken by organizations with a broader remit then ITLET standardization, such as the World Wide Web Consortium (W3C) and the Internet Engineering Task Force (IETF), inform both discourses in this paper?
- How many abstractions can adequately represent a SLE?
- How will we ensure that the developed SLE standardization framework is grounded in sound and stable theories of learning, so that it withstands new trends in pedagogical practices?

Our analysis suggests that for both fields of analysis – research into smart learning and ITLET standardization – there is a need for conceptual development that establishes frameworks that will guide and encourage further development. In this paper, we have developed two models, a core model of smart learning processes (Fig. 6), and a model of characteristics of the environment, in which smart learning take place (Fig. 8). Our claim is that these models can inform the development of an ITLET standardization agenda. For example, there are no activities in early 2018 on data-driven, self-organized learning environments – the highest smartness level represented in Fig. 8. However, if the core model described in Fig. 6 is used to develop requirements for such an agenda socio-cognitive issues are bound to be raised. Among questions asked would be: *How will self-organized environments support socializing? How are artefact creation being facilitated? And how are practice and reflection observed and acted upon to self-adjust the environment?*

Above, we have noted that APIs more and more will be points of interoperability; and as interoperability is often a prominent goal of standardization one could declare job done if the results from the services the APIs connect to fulfil requirements. The problem, however, with this approach is that large parts of the infrastructure will be black boxes outside the scope of both standardization and public knowledge. This is hard to avoid when relying on AI technologies and big data, which are integral parts of self-organizing systems. The understanding of what algorithms do behind the scenes is limited; and the logic developing them is very different from what happens in standardization. This poses challenges to designing a framework to drive further standardization of SLEs since the top-down, deductive logic of traditional standards-making is not what makes data-driven, incremental machine-learning work.

In progressing the abstract modelling work there is clearly a case for the development of a formal ontology describing the field based largely on the work done by Uskov et al. (2015). The problem with a conceptualization of SLE that is too loosely defined is that it will be too weak to guide further research. The same observations hold for the IT architectures we have analysed. In emphasizing the heuristic and pragmatic aspects of framework development there is a need to be explicit about the defining criteria for which direction to go. We would suggest that it is essential to clarify stakeholder perspective and domain relationship. A clearer stakeholder perspective and better understanding of the domain in which the solutions will be implemented will serve as an antidote to the technology focus that has characterized both fields. The range of content and delivery modalities, the ubiquity of learning, and the variety of facilitation – both human and machine supported – all make it clear that a one-framework-fits-all approach is obsolete. Therefore, we suggest a developing strategy that follows a two-pronged approach as follows.

First, create a top-level framework that is simple, robust, and informed by pedagogical perspectives that are themselves informed by innovation with digital technology. The model described in Fig. 6 is in our opinion a candidate for further development. Second, create smaller, well-defined domain models from different stakeholder perspectives, e.g., model describing ITLET environment for learner in math at primary education, or model describing ITLET environment for language teacher in online and distance learning.

The justification for suggesting this approach is the state-of-affairs implicit in the emerging field of SLE. From a situation of rapid change and influx of new technologies we can assume that technological problems are to be solved; there are now other issues related to semantic, organizational, legal and political interoperability that are the barriers. Therefore, in standards development we need frameworks that serve a broader agenda than only technical interoperability. In the field of SLE, there is a need for frameworks that support a research agenda as well as a political agenda of being ‘smart’. Our analysis also suggests that some specific strategies for making progress would involve scrutiny of SLE test implementations and reference models of published standards to assure that modelling of the framework is based on stakeholder requirements. Therefore, to achieve optimum outcomes, it is important that further development takes place in collaboration between research and development, the standards community, and end-users testing out systems under proposal.

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