Conformance Testing, the Elixir within the Chain for Learning Scenarios and Objects

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Abstract. The chain for learning scenarios and learning objects includes five iterative links: (i) development, (ii) publication, (iii) making resources searchable and reusable and (iv) facilitating their arrangement (v) towards a runnable unit of learning. The use of e-learning specifications and components-based systems preferably embedded in a service-oriented architecture are both conditio sine qua non for enabling this chain. However, some of the links are currently below optimal strength. To create a stronger more enduring chain, it must be easier to develop systems compliant to e-learning specifications and users must be better equipped to adopt such systems. Conformance testing(CT) facilitates this adoption, making CT the elixir within the chain for learning scenarios and learning objects. The role of CT within this chain is demonstrated by applying the CT-system from the Telcert project while addressing the strength and weaknesses of each link. Future implications for the chain and CT will be discussed.

1 Introduction

The shift towards a knowledge society asks for competencies that can only be accomplished through complex learning processes – often on the job - where knowledge, skills, and attitudes are integrated and coordinated during task execution and in which tasks often need multiple inputs from several people representing different perspectives. Furthermore, limited financial resources in an ever-expending domain for learning urge educational providers to cooperate on a more global scale. Professional educators are challenged to think about integrating teaching and learning into every aspect of a person's life and putting this into practice in effective, efficient and attractive ways. This challenge can be accomplished through personalised, flexible learning without constraints of time and place and by optimally exploiting the continuous evolution of new information and communication technologies, nowadays often termed Web 2.0 [1]. Lifelong learners are not merely the passive consumers of learning experiences and learning content, but may also enable learning experiences and produce learning content that is relevant to other learners [2]. We will first elaborate on new ways of learning and the possibilities of new technologies before addressing our main question for this article: How to exploit new technologies in an

optimal way (i.e., providing cost-efficient, effective, attractive e-learning experiences)?
The shortest possible answer to this question is: incorporate conformance testing within the chain for learning objects and scenarios. The relationship between conformance testing and its implications for learning is sketched in Figure 1.

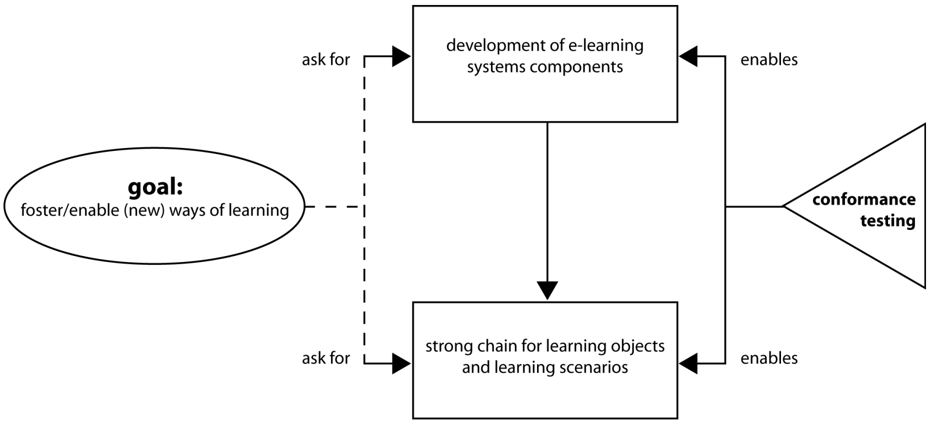

Fig. 1. Conformance testing laying the foundations for fostering new ways of learning.

1.1 New Ways of Learning

New ways of learning (collaborative learning [3,4], competence-based learning [5,6] and problem-based learning [7,8]) imply multi-user *learning scenario's* where knowledge is co-constructed by a community of learners to solve real problems in realistic situations, and are often based on constructivist principles [9-13]. In a learning scenario the application of *learning design knowledge* takes place by describing the learning approach and the teaching-learning process (i.e., the process undertaken by persons interacting within a learning environment). A learning scenario describes the various roles (e.g., teacher, student, assessor) and associated learning and support activities in the learning environment consisting of resources (including *learning objects*) and services. Instead of learning scenario, terms like lesson plan and learning method can be used. Learning design knowledge (see [14,15]) is knowledge that offers explicit prescriptive guidance on how to help people learn and develop: it offers probabilistic guidelines as to what method or methods (i.e., learning approach) can be used better to attain a certain learning outcome. This can be formalized as: *If* learning situation S, *then* use learning method M with probability P. Although such rules do not guarantee complete success, the probability of finding a good solution increases when (i) it has been thoroughly tested in practice by research, (ii) is derived from best practice, or (iii) stems from pattern analysis in collections of comparable best practices [16,17]. Learning scenarios (i.e., learning methods) can be described in such a way that they can be (partly) reused in other settings.

We use a refined definition of learning object, being any digital, reproducible and addressable resource used to perform learning or support activities, and made available for others to use [18]. This definition excludes *courses*, in which a course is a learning scenario structured composite of activities and resources (including learning objects) and services. In fact, in this definition learning objects are restricted to 'learning content' whereas 'learning processes' are reflected in the learning scenario. This aim to separate learning objects from learning scenarios is in line with most recent developments in the field of e-learning (see [19,20]) and – in our view – is a necessary prerequisite for exploiting technologies for new ways of learning. It offers the e-learning landscape the opportunity to be free from the people-to-content model and it gives room to boost reusability of both learning objects (in the restricted definition) and learning scenarios. This definition of learning object also excludes non-digital, non-addressable resources. When the issue of reusability comes into account, non-digital, non-addressable resources are clearly out of scope.

In the people-to-content model, learners gain knowledge in a single user-scenario primarily by passively digesting content. It is evident that this does not match with the scenario sketched in the introduction and demand from our society. Technologies are indispensable but not sufficient to reach the Holy Grail of reusability for both learning objects and learning scenarios. This article mainly addresses the issue of reusability from a technology enabling viewpoint whereas the changed development paradigm for learning objects and learning scenarios will only be briefly touched on because a more extended discussion of this is beyond the scope of this article (see [21]).

1.2 Possibilities of New Technologies

Personalised, flexible and new ways of learning ask for innovative supporting technologies. *Educators* (teachers, educational designers, and so on) strive for maximum flexibility to develop learning materials (i.e., learning content) by editing and adjusting learning objects and aim for maximum flexibility to develop learning processes by editing and adjusting learning scenarios. Learners need a personalised learning experience and maximum flexibility when interacting with such learning materials. Finally, educational institutes need maximum flexibility to respond to ever-changing – most local - demands in a cost-efficient way to sustain the e-learning business. Innovative technologies should support all three before-mentioned stakeholders (educators, learners, educational institutes) in an optimal and cost-efficient way. This support consists of two pillars: (i) learning technology (LT) specifications, and (ii) components-based e-learning systems, preferably embedded in a service oriented architecture (SOA). The various e-learning technology specifications when used with components-based e-learning systems embedded in a SOA provide comprehensive support for new ways of learning. We will firstly elaborate on LT specifications before addressing the topic of components based e-learning systems and SOA.

1.2.1 LT Specifications

LT specifications are recorded in a clear, abstract and formal way, can be locally adapted, and are ‘open’ to promote widespread uptake by stakeholders. These specifications are described in this way in order to meet the need for reusability and interoperability, and also because such specifications aim at recognition by standardisation bodies: the ultimate goal for a LT specification is to become a standard. However, by 2005, most LT specifications have not reached this stage.

An important LT specification which only supports traditional ways of learning but also, more importantly, new ways of learning is IMS LD [22], referred to as LD from now on. This specification supports the approach of separating learning objects and services (modelled outside LD) from the educational method and (learning or support) activities (modelled inside LD). In other words, in LD, learning objects and learning scenarios are clearly distinguished. LD is used to model a so-called unit of learning (UoL) which could be a course, a module, a lesson, and so on. In a UoL, people act in different roles in the teaching-learning process while working towards specified outcomes, by performing learning and/or support activities with an environment. The environment consists of learning objects and services to be used during the performance of the activities [23,24]. LD is a comprehensive standardised notation in line with other specifications (e.g., LOM, IMS CP, IMS QTI) which supports blended learning as well as pure online learning, is pedagogically neutral, enables in principle personalisation and reusability, and can be automatically processed [25]. Currently, more research is being conducted to evaluate how well LD covers educational expressiveness [26] and how well it covers personalisation issues. Although the ideal LT specification to support new ways of learning may still be lacking, LD definitely is a giant step forward.

1.2.2 Components-based e-Learning Systems and SOA

The components-based approach for e-learning systems embedded in a service oriented architecture (SOA) is needed to achieve high quality e-learning experiences (see [27, 30]). Technology nowadays plays a central role in the way education is managed and provided and it therefore makes much sense to look at the most recent developments in the worlds of IT and Business. In these worlds, a paradigm shift is taking place in the way applications are being put together, moving away from large monolithic systems that play specific roles, to an approach that involves putting the smaller building blocks together in a more flexible way. Such environments are often highly distributed and competitive with very tight profit margins and development time scales. The development or purchase of large systems is increasingly problematic due to their great cost, and their inability to share data with other systems. New technologies in the form of web services and SOA provide a way forward for achieving high quality e-learning experiences by supporting a flexible and sustained approach to e-learning systems: “In a service oriented approach the application logic (behaviours) contained in various systems across the educational organisation – such as student record systems, library management systems, LMS/VLE directories and so on are exposed as services, which can then be utilised (consumed) by other applications. For example, a student record system may expose services defining enrolment and registration processes and related information, which can then be used by a LMS/VLE or library system" [31].

For a range of web services from a variety of sources to be able to work together, they must conform with a set of technical standards (i.e., LT specifications) to enable them to "talk to each other". When web services are joined up with each other and/or other applications to meet the needs of a particular user (a business, a faculty, etc), this is done through a service-oriented approach [32]. This approach produces so-called *composite applications* that mean that (a) individual services can be replaced by others without having to get rid of the whole system, (b) that existing systems can interact with new applications, and (c) that applications can be developed that better fit the needs of the users. Undeniably, this kind of flexibility is urged by educators, learners, and educational institutes to enable personalized, flexible and new ways of learning in a cost-efficient way ('best of breed'). However, it is difficult to judge whether the completely different funding model in the case of education makes it justifiable to make serious levels of investment in new and more efficient (pedagogical) approaches as would be the case from a business point of view. It is possible to spread or 'pool' the necessary investments with other educational institutes using Open Source Software (OSS) instead of outsourcing/buying a customized proprietary components based e-learning system. OSS offers the possibility of preventing a vendor lock-in, although a mixed mode of OSS and proprietary components based e-learning system could become prevalent in the Web 2.0 era. For e-learning, as in e-commerce and e-business, systemic changes wrought by emerging technologies are also changing the relationships between consumption and production - in this case of knowledge - as what many call 'Web 2.0' becomes more interactive and user-generated content becomes more widespread [33].

To summarize, innovative technologies support new ways of learning through the two pillars of (i) LT specifications and (ii) components-based e-learning systems embedded in a SOA. But how can one exploit these technologies in an optimal way?

1.3 Exploiting New Technologies in an Optimal Way

A chain for learning objects and learning scenario's based on LT specifications and components-based e-learning systems embedded in a SOA exploits new technologies in a meaningful way with a challenging, fruitful perspective on exploiting such technologies in an optimal way. The chain (see Figure 2) consists of five links: (1) development of learning objects (LOs) and learning scenarios (LSs), (2) set available LOs and LSs, (3) make LOs and LSs searchable and reusable, (4) arrange LOs and LSs into units of learning, (5) use units of learning by learners and educators. The chain is an adapted and extended version of the one used by Kennisnet [34]. The latter chain is restricted to learning content.

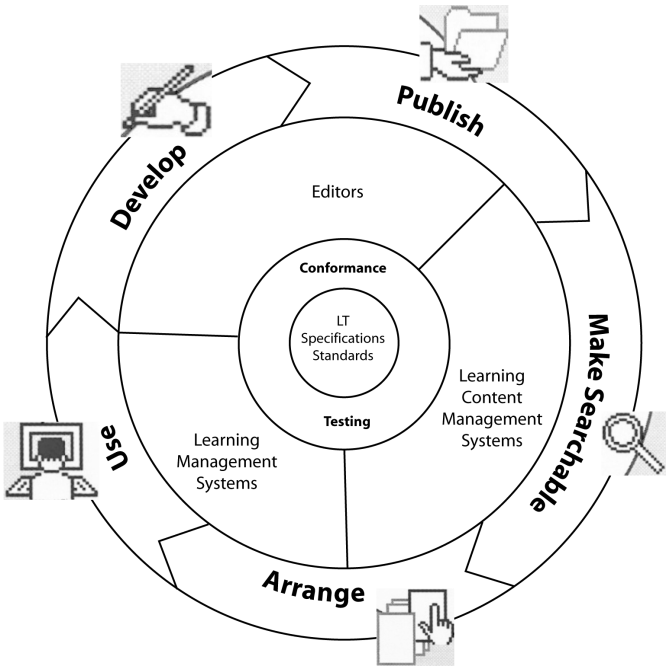

Fig. 2. Chain for learning objects and scenarios

Each of these links work in an iterative fashion, an approach largely resembling the Unified Process approach that is most commonly used in contemporary object oriented software development [35] instead of the more classical waterfall model. For the chain to function properly, a components-based e-learning system embedded in a SOA is needed to support the activities of the five links, and such a system should support appropriate LT specifications. However, currently this chain does not function smoothly. The subsystems for some of the links are far from optimal (time consuming, complex, not user friendly, error prone, not components-based, or not embedded in a SOA) or even unknown to possible users, causing such a link *and* the chain as a whole to be below optimal strength. In this way, cost-efficient high quality e-learning experiences are excluded whereas e-learning experiences that belong to the people-to-content model are encouraged, exactly the opposite what is asked for by our society!

The main challenge is how to arrive at a smoothly operating chain that frees us from solely using the people-to-content model. In general, such e-learning systems should be more easy to use, should cover all functional requirements (which are still evolving) and the user should be in the position of making an easier choice between competing systems. Fortunately, the solution is already at hand and is provided by conformance testing which is likely to boost the development and adoption of user-friendly e-learning system components within the chain for learning scenarios and objects. Conformance testing is a widely used tool in industries such as telecommunications for testing implementations against standards and specifications [36,37]. For e-learning scenarios, objects (i.e., content) and systems also, existing conformance testing techniques can be applied. However, unlike the telecommunications industry where *standards* generally must be strictly adhered to, e-learning *specifications* typically allow a much greater degree of freedom in how the specifications are implemented.

The diversity of e-learning community needs and the different permutations of implementations allowed by e-learning specifications contribute to make conformance testing more complex in this domain, especially as the LD specification to enable new forms of e-learning is regarded as complex [38]. The practice of creating *application profiles* or localized implementations of e-learning specifications is a common method used to cater to community-specific requirements, yet it poses a number of challenges for testing specification conformance. In this article conformance testing for systems is restricted to components-based systems preferably embedded in a SOA or to components as such systems are regarded as a *conditio sine qua non* for exploiting new technologies in an optimal way. So, this restriction does not stem from conformance testing (CT) per se. The Telcert project developed a set of software tools for use in conjunction with established conformance testing principals [39]. Such a CT-system enables a cost-efficient transition to new ways of learning by encouraging development and adoption of in a SOA embedded e-learning system components to be used within the chain for learning scenarios and objects. The next section of this article demonstrates for each link in the chain how the Telcert CT-system can be applied to improve the strength of the link also indicating the current strength of such a link.

2. The Links and Conformance Testing in the Chain for Learning Objects and Scenarios

This section will elaborate on each of the links of the chain for developing learning objects (LOs) and scenarios (LSs) and will conclude with an outline of how conformance testing can be used to strengthen the chain. The use of the Telcert conformance testing tools will also be explained in the context of the chain. To illustrate the chain, a use-case based on LD will be utilised. LD was chosen for this purpose because it is a meta-language for modelling learning designs which enables the rich description of pedagogical models. Other specifications such as the Sharable Content Object Reference Model (SCORM) or IMS Simple Sequencing offer some functionality for LO and LS development and use but do not have adequate support for multi-user scenarios [40].

The use-case will be based on an existing LD Unit of Learning called “Learning to Listen to Jazz” [41] which is an introductory course about Jazz music. The development of the use-case will also highlight the strengths and weaknesses of each link and will include suggestions for improvement.

In this course, students are able to (re)select one of two paths through the course material, one thematic and the other historical. If a student selects the thematic path, the course material is presented around three themes: bebop, free jazz and swing. The Jazz course use-case can be extended from the original example to further incorporate new ways of learning. For example, in the activities on the different streams of Jazz (such as bebop) the students could be given the facility to upload samples of Jazz music for other students to listen to and rate. A discussion group for each of the study paths will be available for students to participate in asynchronous discussions (with an online discussion board) about the different styles of Jazz they are exposed to through the course. Finally, students can be asked to listen to Jazz concerts available online and participate in a synchronous chat session. Both the discussion board and the online concert and chat activities can be made available to both paths (thematic and historical).

A summary of the activities that need to be carried out for each link in relation to the Jazz case-study are as follows:

- Link 1 – develop LOs/LSs: This link will result in the creation of a number of learning objects and learning scenarios and corresponding metadata which make up the Jazz example
- Link 2 – publish / make LOs/LSs available: The learning objects and scenarios developed in link 1 are published and made available for use by others
- Link 3 – make LOs/LSs findable/searchable. Enabling the learning objects and scenarios developed in link 1 to be searched and found
- Link 4 – arrange LOs/LSs: The learning objects and learning scenarios developed in link 1 can now be assembled to form a set of complete courses in this link. These resources may still be used and repurposed in other contexts
- Link 5 – use LOs/LSs: Several complete Jazz courses are run in a LMS, or other system for use by teachers and learners

A sample of the types of software tools available for supporting the chain can be found in Table 1.

Table 1. Sample of Tools Available for the Chain of Learning Objects and Scenarios

Tool	Description	Relevant Link/s
Reload	-Authoring tool based on several specifications (IMS LD, CP, MD) -Plays IMS LD	Link 1 Link 4
AskLDT Editor	-Creates Units of Learning using preset learning scenarios -Supports LD Level B	Link 1 Link 4
CopperAuthor	-Enables the authoring of Units of learning -Supports IMS LD Level C	Link 1 Link 4
MotPlus	-General purpose graphical editor with some support for authoring/ developing Units of Learning in level A	Link 1 Link 4

Blackboard/ WebCT	- Currently two separate proprietary LMS's (the companies are emerging in 2006) which incorporate repositories for storing web-based resources (which may include LOs and LSs). Neither currently support LD	Link 2 Link 5
Moodle	Open-source LMS which also includes a repository for storing web resources. Currently no support for LD, but there is work underway	Link 2 Link 5
CopperCore	LD engine which plays Units of Learning	Link 5
CopperCore player	Reference player with the CopperCore LD engine. Supports LD Level C	Link 5
SLeD player	Player which supports LD Level C and uses CopperCore LD engine underneath	Link 5
Merlot	Repository for Learning Objects (requires metadata to be entered manually)	Link 2 Link 3
Careo	Repository for Learning Objects (requires metadata to be entered manually)	Link 2 Link 3

In the following section, each link is examined in more detail, outlining its strengths and weaknesses.

2.1 Link 1 – Develop Learning Objects / Learning Scenarios

The outcome of this link is a set of learning objects and scenarios that have been developed to maximise their potential for repurposing and reuse. Individual LOs may be reused in other Jazz courses, or general music or history courses for example. LSs may be reused similarly, and could be repurposed for other web-based courses.

Learning objects can be developed in a wide number of general software applications depending on their format. For example, a piece of introductory text on Jazz may be presented as an MS Word document, a PDF file or as HTML text. In order to package this learning object in a standard way, a packaging specification such as IMS CP [42] can be used.

In the original example, the Jazz course was created as a single learning scenario which was represented in the LD Unit of Learning. However, each path (thematic or historical) could also be considered as a separate learning scenario for the sake of reuse. Furthermore, the theme-based learning scenarios (bebop, free jazz and swing) could further be mapped as separate learning scenarios. One can easily imagine several other Jazz-themes or even a further subdivision of themes.

2.1.1 Link Strengths

There are a wide range of both specialised and generic software tools available to developers of learning objects (i.e., content) and there has also been much recent activity in tool development in the open source field. Learning objects may be created in a number of different general software tools such as Dreamweaver MX™ for creating webpages or MS PowerPoint™ for slides (Table 1) to name just a few examples. Well established e-learning specifications for content packaging and metadata exist and can be localised for use in consistently describing and packaging such resources. Tools such as Reload (Table 1) enable the user to package a LO or Unit of Learning (UoL) in an IMS Content Package.

2.1.2 Link Weaknesses

Current LD-authoring tools such as Reload, CopperAuthor, ASK LDT and MOT Plus enable the creation of UoLs, but do not facilitate the development of individual LSs or the extraction of LSs from within existing UoLs for the purposes of reuse. Conformance to the entire LD specification is sometimes incomplete (Table 1). As these tools are relatively new, they may not yet be fully tested, could contain unexpected bugs and may not be considered user-friendly enough for wide-spread adoption. Tools such as Reload and CopperAuthor are quite close in concept to the LD specification which means that users require an in-depth understanding of the specification itself. This limits their appeal as course development tools. Generic software tools such as MS Powerpoint™ do not support e-learning specifications.

2.2 Link 2 - Publish / Make Learning Objects and Scenarios Available

The Jazz LOs and LSs created in Link 1 can now be published in a LMCS (Learning Content Management System) or a more general repository. This process makes them available for use by others, therefore promoting reuse and improving collaboration opportunities by providing the means to share resources with a much wider group of users than was traditionally possible. The Jazz LOs and LSs can now be added to an open repository such as MERLOT and made publicly available (subject to copyright restrictions that may exist).

2.2.1 Link Strengths

Open repositories such as MERLOT and Careo (Table 1) are well known and contain large numbers of resources for teaching and learning. Resources found in such repositories could be LOs, LSs, or more commonly LOs which are intertwined with LSs, with no distinction made between the two concepts. Many Learning Management Systems such as Moodle and WebCT incorporate a repository for storing resources for teaching and learning, which blurs the distinction between LMS and LMCS.

2.2.2 Link Weaknesses

Tools may not fully conform to e-learning specifications, causing interoperability issues between LOs/LSs and repositories. Dominance of software such as Blackboard/WebCT can make it more difficult to promote truly portable LOs/LSs based on open standards. If a LMS incorporates a repository, it might not be possible to access it using the LMS interface and so storing LOs and LSs in an LMS can restrict their potential for reuse.

2.3 Link 3 - Make Learning Objects and Scenarios Findable/Searchable

After putting learning objects and scenarios such as the Jazz examples created in Link 1 into a repository, they need to be made searchable/findable so that they may also be found and used/repurposed by others. The act of adding a LO or LS to a repository therefore usually also involves the creation of metadata. Automatically generated metadata reduces the efforts of users to add learning objects to a repository, and has been demonstrated as potentially more effective and consistent than manually generated metadata [43]. In relation to the use-case, our LOs and LSs will now have descriptive metadata, including pedagogical metadata attached to it. For example, information can include author details, usage limitations, intended audience and level of difficulty.

A federated search gateway enables searches across different repositories. The use of so-called *search profiles* supports finding learning objects and scenarios. For example, the EduRep-project [44] of Kennisnet in the Netherlands will enable learners and teachers in their own LMS to search for and find adequate learning objects and resources through a portal. MERLOT has also produced a federated search facility which allows searches across a number of repositories [45].

2.3.1 Link Strengths

Search engines and federated search gateways for Learning Object Repositories enable users to find objects from a wide range of sources. Not surprisingly, libraries in particular have been active in this field and numerous federated search tools are in use in libraries [46]. Research has shown excellent results for automatically generating metadata and there is a lot of information available about how to create it. Many communities such as Ariadne [47] have developed their own metadata profiles.

2.3.2 Link Weaknessess

The current generation of repositories such as Merlot do not have any functionality for distinguishing learning scenarios from learning objects. Creating metadata by hand can be a time-consuming and laborious task and preferably should be avoided. Search engines such as Google produce effective search results using full-text indexing of web resources without the use of metadata. Non-text objects cannot be easily indexed automatically and may require manually created accompanying metadata to catalogue them [48].

2.4 Link 4 – Arrange Learning Objects and Scenarios

Learning objects and learning scenarios need to be assembled to form single units of learning before Jazz courses can be used for teaching and learning. By using the LD specification, the process of assembling a course results in a playable version of the course populated with learning objects, people and services. The development of a Jazz course may also include searching for additional LOs and LSs that could be repurposed or reused.

2.4.1 Link Strengths

Tools currently available such as Reload (Table 1) offer support for new ways of learning.

2.4.2 Link Weaknesses

Tools such as Reload and CopperAuthor (Table 1) are not designed to import or export individual LSs from a complete UoL, which limits their potential for reuse. Furthermore, as already discussed in Link 1, the software available for authoring UoLs is relatively new and could contain some bugs. This might also effect conformance to the e-learning specifications used (particularly LD itself).

2.5 Link 5 - Use of Learning Objects and Scenarios

In this link, the LOs and LSs are used in actual teaching and learning situations. After assembling a Jazz Unit of Learning from the composite LOs and LSs into a course, the UoL can now be played in a player such as the SLeDPlayer (Figure 3) and made available to students. The course has now moved into the exploitation phase.

2.5.1 Link Strengths

Although a number of software tools for playing LD such as the SLeD, CopperCore and Reload players (Table 1) have emerged in recent years, there are none yet available which could be considered a truly “personal learning environment” [49]. In our opinion the strength of this link leaves much room open for improvement.

2.5.2 Link Weaknesses

At present, the user has very limited freedom to adjust the learning environment to his or her needs, being a considerable way off from having a Personal Learning Environment. A seamless integration of components-based e-learning systems in delivering e-learning has not yet been reached [50,51]. This means that a cost efficient and automated way of supporting new ways of learning (for example multi-user scenarios and peer assessment) is not currently available.

Fig. 3. Viewing the Jazz Course in the SLeD Player

2.6 The Role of Conformance Testing in the Chain

Conformance testing can be play two important roles in the chain for learning objects and scenarios. Firstly, it can be used to ensure the LOs and LSs themselves conform to the e-learning specifications they are based on. Conformant and error-free LOs and LSs will be more interoperable with other systems and content. Conformant metadata records should help with search and discovery and to facilitate metadata harvesting initiatives. Conformance testing can also be used by user communities to test LOs and LSs against their application profiles (localised versions of e-learning specifications) to determine whether they are compatible.

Secondly, the software tools that are used to create, modify, store, repurpose and play learning objects and scenarios should also be conformance tested to ensure they comply with relevant e-learning specifications and to facilitate faster and cheaper software development for these tools. This would in turn strengthen the links in the chain where more software components are required (such as Link 5), or need improvement (Links 1 to 4). From the perspective of the Jazz example, the LOs and LSs developed in Link 1 could be tested to ensure they conformed to the e-learning specifications they were developed with (such as IMS LD, CP, QTI, etc.).

In the e-learning specifications field, there are two broad barriers to the adoption of effective conformance testing processes. Firstly, many small software development projects may not have the resources for comprehensive conformance testing. Secondly, the use of application profiles and domain profiles (sets of application profiles) complicates the conformance testing tasks faced by e-learning developers. In order to address these issues, the Telcert project [51] has developed a set of tools for conformance testing which can be used in conjunction with existing conformance testing techniques to simplify and speed up the testing process.

The Telcert conformance testing tool-set supports the links in the chain for LO and LS by enabling the following tasks:

- User communities can modify e-learning specifications (create Application Profiles) to suit their needs, thereby encouraging and facilitating the use of specifications (a key prerequisite for interoperability).
- Enabling the testing of LOs and LSs against the specifications they are based on and providing detailed test results
- Creation of test instances (eg. Sample LOs and LSs) which can be used for conformance testing in the software development process, thereby automating an often laborious task

Better conformance testing in the e-learning domain will simplify and improve software development in this domain, and increase confidence in software products among users. LOs and LSs will also become more portable between different systems.

3. Discussion

Conformance testing is indispensable for creating a stronger more enduring chain for learning scenarios and objects. It is the elixir for a cost-efficient transition to new ways of learning by encouraging both the development and adoption of e-learning system components embedded within a SOA to be used within the chain. Furthermore, it enables more portable learning objects and scenarios between different systems. Finally, conformance testing downgrades the prevalent role of the people-to-content model in the current e-learning landscape in favour of entering the era of effective and attractive lifelong learning in an affordable way [52-54].

However, this huge potential for conformance testing could be left sub-optimally exploited or even unexploited because of four reasons. First, the promise of CT could fail to meet expectations because the adoption of e-learning specifications in order to achieve innovation in e-learning is not taken up by a substantial proportion of the e-learning community. When encouraging a community in diffusing an innovation, their decision to adopt or reject is made on the basis of five innovation attributes [55]: is there enough relative advantage in economic terms or social prestige (i), is it compatible with current practice (ii), is it simple to use (iii), is it easy to experiment with (iv), are its benefits clearly visible (v). In our opinion, an unequivocal yes to all five questions is currently lacking and this may be the reason why there are still many educational institutes hesitating to actively use e-learning specifications. This hesitation could be intertwined with people's natural aversion (i.e., business culture) towards change [56].

Secondly, the real benefit of CT could fall below expectations because it turns out to be unfeasible to develop components that are both user-friendly and easy to use.

As the weakest link determines the strength of the chain, one weak link in the chain could be detrimental to the impact of CT for the whole chain. For example, although there has been a lot of progress, current editors for development and arrangement still need a lot of experience and expertise to be put into effective use [57].

Thirdly, although CT is well known, it is still quite new in the e-learning industry. As such, there are some limitations to current CT-test systems that should be by-passed in the near future in order to get optimal benefits from CT. Two important limitations of the current Telcert test system are that it is (i) is not able to test requirements spanning multiple interdependent specifications (for example IMS LD and IMS QTI) and (ii) generic conformance rules contained in written documentation (as opposed to the specification XSD representation) must be manually identified and entered into this test system for each new specification that is required to be tested. The project is currently working on solutions to both of these issues for the second phase of the tool-set (due July 2006). The issue of generic conformance rules being derived from documentation further highlights the necessity for unambiguous documentation. Clearly it would be better to be able to specify all requirements in a machine-readable, unambiguous way. The limitations of XML Schema have led to the development of a number of alternatives to replace or supplement an XSD file [58]. UML offers the possibility for representing e-learning specifications in an implementation-neutral manner, however this is not yet common practice.

The fourth and final reason for not optimally exploiting CT benefits could result from the specific funding models used by educational institutes, which does not encourage the development of explicit policies on CT, OSS and e-learning. In such circumstances, CT could be underutilized or even be unused, especially if educational institutes can afford a homebrew e-learning system that is not compliant with e-learning specifications.

More mature conformance testing should be actively promoted and valorised to gain wider adoption, leading to more effective exploitation of its potential for promoting new ways of learning. The Telcert project suggests this route for adoption and highly recommends using an independent third party to sustain and extend CT-systems for e-learning as well as for performing verifications of conformance. As such, CT in itself cannot bring about new ways of learning, but it will certainly make life much easier for educationalists striving to exploit effective and attractive lifelong e-learning experiences in our modern society.

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