ELEARNING FRAMEWORKS: A SURVEY

José Paulo Leal

DCC/FCUP & CRACS
Porto/Portugal
zp@dcc.fc.up.pt

Ricardo Queirós

DI/ESEIG & CRACS
Porto/Portugal
ricardo.queiros@eu.ipp.pt

Abstract

In recent years the concept of eLearning Framework emerged associated with several initiatives promoted by educational organizations. These initiatives share a common goal: to create flexible learning environments by integrating heterogeneous systems already available in many educational institutions. The paper provides an introductory survey on eLearning Frameworks. It gathers information on these initiatives categorizes them and compares their features regarding a set of predefined criteria such as: architecture, business model, primary user groups, technical implementations, adopted standards, maturity and future development.

Keywords - SOA, interoperability, services.

1 INTRODUCTION

In recent years the concept of eLearning Framework emerged associated with several initiatives promoted by educational organizations. These frameworks address the heterogeneity of the hardware and software environments found in most educational institutions, many of which are not replaceable and are extremely important to the institution. These initiatives allow institutions to develop their own architectures, using a Service Oriented Architecture (SOA) [1]. In SOA the application logic is exposed as services, which can be used (consumed) by other applications. These frameworks provide several layers of services to support the development and management of eLearning systems.

The goals of this paper are to gather information on eLearning frameworks, to categorize them and to compare their features. For this study we selected frameworks including eLearning in their targets and with a reasonable amount of documentation. We start by tracing the evolution of eLearning systems towards the emergence of the concept of eLearning framework. We proceed with the analysis of abstract frameworks, whose goal is the creation of specifications, recommendations and best practices for eLearning frameworks. Concrete frameworks, that we analyse in the following section, provide also the design of complete services as well as components that can be integrated in actual implementations. Finally, we synthesize the frameworks presented in the previous sections and we compare them regarding a set of predefined criteria such as: architectural models, user groups, adopted standards, impact and maturity. We conclude the paper with a summary of the current trends in eLearning frameworks development and open challenges for research on this subject.

2 EVOLUTION TOWARDS E-LEARNING FRAMEWORKS

The architectures of eLearning platforms had a considerable evolution in the last two decades. Starting with the early monolithic systems developed for specific learning domain to domain-independent systems featuring reusable tools that can be used virtually in any eLearning course [2]. These last systems follow a component oriented architecture in order to facilitate tool integration. Integrated environments have been successfully used to leverage the advantages of ICTs, but have also been target of criticism. These systems based around pluggable and interchangeable components, led to oversized systems that are difficult to reconvert to changing roles and new demands such as the integration of heterogeneous services based on semantic information, the automatic adaptation of services to users (both learners and teachers), and the lack of a critical mass of services to supply the demand of eLearning projects. These issues triggered a new generation of eLearning platforms based on services that can be integrated in different scenarios. This new approach provides the basis for SOA. In the last few years there have been initiatives [3, 4] to adapt SOA to eLearning. These initiatives, commonly named eLearning frameworks, had the same goal: to provide flexible learning environments for learners worldwide. Usually they are characterized by providing a set of open interfaces to numerous reusable services organized in genres or layers and combined in service usage models. These initiatives use intensively the standards [5, 6] for eLearning content sharing and interoperability developed in the last years by several organizations (e.g. ADL, IMS GLC, IEEE).

3 ELEARNING FRAMEWORKS

Over the years the word *framework* has been used to define a work environment specially designed to solve common and complex problems in different domains. Due to its broad definition it is often used as a buzzword, especially when applied to software. A software framework may include support programs, runtime environments, code libraries and other tools, in order to assist the developer in a software project. Usually the functions of a framework are exposed through an Application Program Interface (API). The code provided by the framework is usually divided in *frozenspots* (services already developed in the framework) and *hotspots* (set of common code that must be overridden or specialized by user code) [7]. Hence, this twofold code feature amongst with the inversion of control is one of distinguishing keys that separate the current frameworks from generic code libraries.

An eLearning framework can be defined as a specialized software framework. In the eLearning field, this term has been associated with several initiatives to adapt SOA to eLearning. Based on Service Oriented Approaches [8], the process of moving from a framework to a working implementation can be defined by four key concepts:

- A **Broad Vocabulary** describes all possible ‘services’ for a domain such as eLearning;
- A **Reference Model** combines these services for specific learning or teaching requirement;
- A **Design** specifies the use of standards and specifications for these combinations;
- An **Artifact** is an implementation (software, process, workflow) of a design.

The relationship of the key concepts of eLearning frameworks is shown in Fig. 1. A Framework provides a vocabulary of Services (e.g. digital repositories services), from which a Reference Model (e.g. describing content management) is derived. A particular Design (e.g. repository management application) is modelled based on the Reference Model which is then implemented as an Artifact.

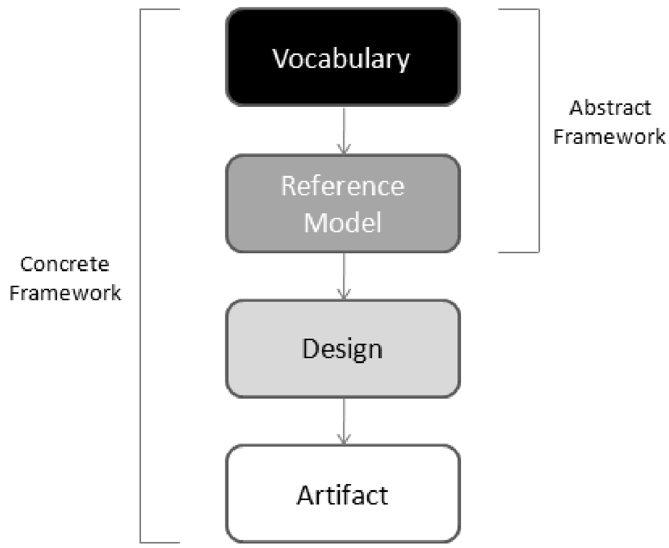

Figure 1 – Simple Framework model.

Based on these key concepts, we group them in abstract and concrete frameworks. While **abstract frameworks** provide a broad vocabulary and a reference model for the development of eLearning systems, **concrete frameworks** provide also designs and/or artifacts. In the remainder of this section, we categorize eLearning frameworks based on these groups.

3.1 Abstract Frameworks

Abstract frameworks aim only at the creation of specifications, recommendations and best practices for the development of eLearning systems. In this subsection we detail three initiatives belonging to this category, more precisely, the IMS Abstract Framework, the Open Knowledge Initiative and the IEEE Learning Technology Systems Architecture, in the chronological order of their first definition.

A. IEEE Learning Technology Systems Architecture

The IEEE Learning Technology Standards Committee (LTSC) is chartered by the IEEE Computer Society Standards Activity Board to develop internationally accredited technical standards, recommended practices, and guides for learning technology. The IEEE LTSC has developed a number of internationally accredited standards. The IEEE Learning Technology Systems Architecture (LTSA) is one of the standards that define a pedagogical and implementation neutral high-level architecture for information technology-supported eLearning systems [9]. This standard, whose first draft was presented in 1996, covers a wide range of systems and promotes interoperability and portability by identifying abstract, high-level system interfaces.

The LTSA system components [9], depicted in the Fig. 2, identify the abstract and high-level interfaces for eLearning systems. The LTSA system components are based on:

- Processes (depicted as gray rectangles): are described in terms of boundaries, inputs, process (functionality), and outputs.
- Stores (depicted as black rectangles): are described by the type of information stored, and by search, retrieval, and updating methods.
- Flows (arrows): are described in terms of connectivity (one/two-way, static/dynamic connections, etc.) and the type of information across the flow.

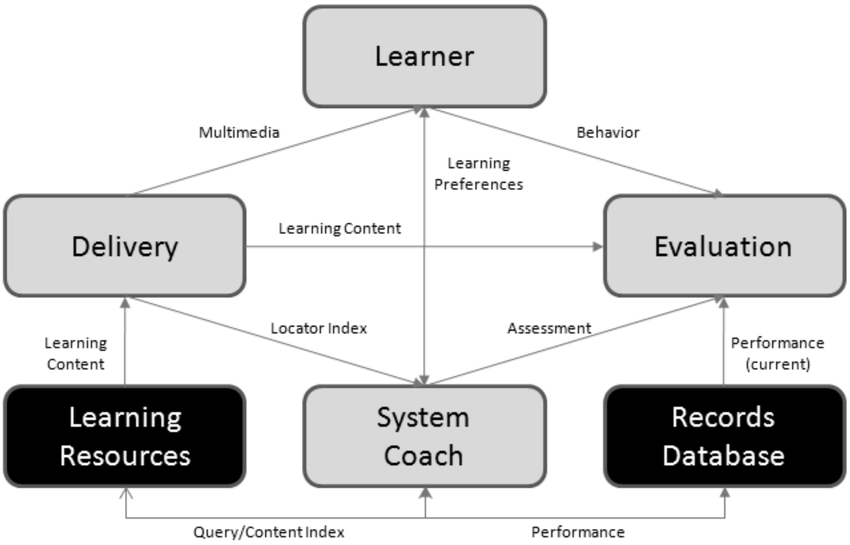

Figure 2 – Learning Technology System Architecture.

Currently the LTSA working group status is defined as inactive at the web site of this project [10].

B. Open Knowledge Initiative

The Open Knowledge Initiative (OKI) is a project created in 2001 and is currently leaded by the Massachusetts Institute of Technology (MIT). The main goal of this project is to provide a framework for higher education learning systems. The result of this initiative is an open and extensible architecture that specifies, based in the concept of Open Service Interface Definition (OSID), how the components of an educational software environment communicate with each other [10]. The OKI OSIDs define standard interfaces that allow one application (an OSID consumer) to access specific data and functionality from another application (an OSID provider).

For example, a digital repository can make its collections of learning objects accessible to a learning management system (LMS) by exposing an implementation of the Repository OSID. The LMS then needs only to call functions of the digital repository as defined by the OSID. An architectural view of the framework [10] can be seen in Fig. 3.

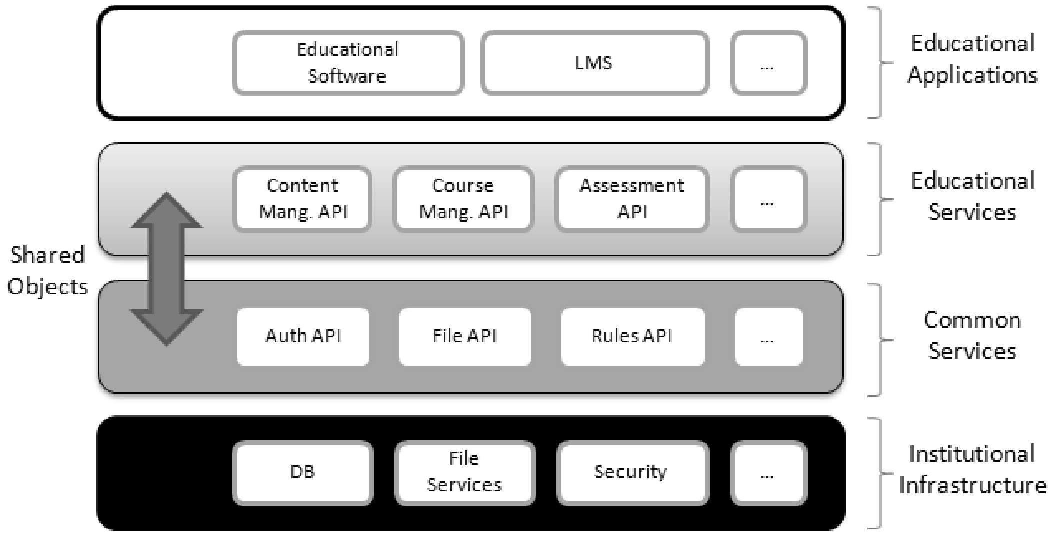

Figure 3 – OKI architecture.

Recently, OKI has produced a Java OSID binding [11]. There are also bindings for other programming languages such as PHP, MS .NET and C#. In 2005, OKI announced the creation of XOSID (XML OSID) providing a language neutral XML representation of the OSIDs, which until the date were only available as Java APIs.

C. IMS Abstract Framework

The Instructional Management Systems - Global Learning Consortium (IMS GLC) is a global coalition of academic, commercial and government organizations, working together to define the Internet architecture for learning. The IMS Abstract Framework (IAF) is an abstract representation of the services and their interfaces that comprises eLearning systems [12], providing a context for IMS to develop its specifications. The IAF is represented as a layered model [13], as shown in the Fig. 4, consisting of four layers:

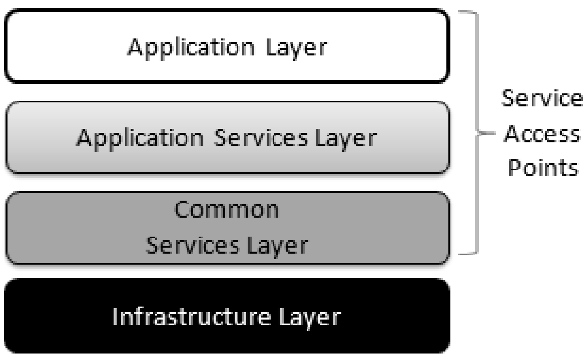

Figure 4 – IAF layered model.

- Application layer - set of systems, tools, agents, etc. providing a set of eLearning functionality;
- Application services layer - set of services providing a specific eLearning functionality to the applications (e.g., course management);
- Common services layer - set of services providing the generic services to be used by the application services (e.g., authentication);
- Infrastructure layer – set of services enabling the exchange of the data structures in terms of physical communications.

The access to a service is made through its Service Access Point (SAP). Each service has a single SAP but, being an abstract framework, IAF does not address the implementation of SAPs. It should be mentioned that this specification has not been updated since 2003.

3.2 Concrete Frameworks

Concrete frameworks extend the goals of abstract frameworks by providing also complete service designs and/or components that can be integrated in actual implementations of artifacts. In this subsection we detail four initiatives belonging to this category, more precisely, the E-Framework, the Schools Interoperability Framework and the Open University Support System, in chronological order of their first definition.

A. Open University Support System

The Open Source University Support System (OpenUSS) is a project to make a virtual university platform under an open-source license [14]. The OpenUSS is a part of the CampusSource intitiative, set up by the state of North Rhine-Westphalia, Germany. The OpenUSS is based on a component-oriented architecture divided into two components:

- Foundation Components: represent the main and domain-oriented components like Assistant, Student, Enrollment, etc.;
- Extension Components: represent all the domain neutral functions of OpenUSS such as Discussion, Chat, Lecture, etc.

Whilst the primary user groups are universities, the community of developers can contribute with APIs and reference implementations for the OpenUSS. OpenUSS is currently implemented in several universities in Germany and Mexico and over 10000 users rely on it worldwide. Nevertheless, OpenUSS has not been updated since 2001.

B. Schools Interoperability Framework

The Schools Interoperability Framework (SIF) is an industry initiative, supported by the SIF Association (SIFA). The objective of SIF is to develop an open specification to enable educational applications, such as K-12 instructional and administrative software applications, to interact and share data [15]. The framework is composed by two specifications: an XML specification for modelling educational data and a SOA specification for sharing that data within a SIF Zone.

A SIF Zone is a logical group of applications, in which software application agents communicate with each other through a central communication point – the Zone Integration Server (ZIS). A SIF Zone consists of a ZIS and one or more software applications with a SIF Agent (a SIF-enabled application) distributing one or more SIF data objects over a network. Fig. 5 shows an example of a SIF Zone [15].

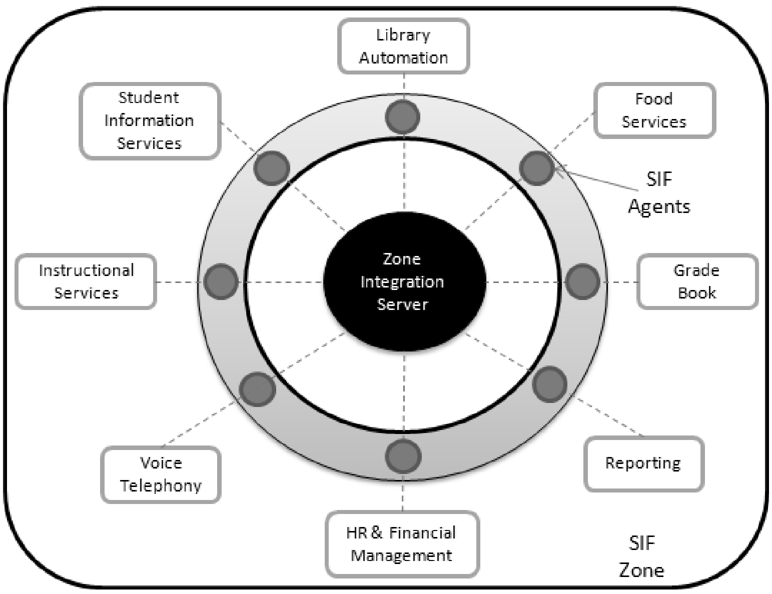

Figure 5 – SIF architecture.

Users are able to develop their own SIF Implementations. A SIF Implementation consists of one or more SIF Zones deployed to meet customer needs. The implementation must comply with the SIF Implementation Specification. This specification defines the architectural requirements and communication protocols for the software components and the interfaces between them. The specification makes no assumption of specific hardware/software needed to develop SIF applications.

Currently, the SIF specification is being used by numerous vendors [16] in all USA states as well in the UK and Australia. The future plans for the framework are the development of a K12 Data Model and an inclusion of a Web Services infrastructure. The new version (2.4) of the Specification is in the final stage of a release cycle.

C. E-Framework

The e-Framework is an initiative that seeks to promote the use of the SOA in the analysis and design of software for education and research [17]. The e-Framework has four funding partners (UK – JISC, Australia – DEEWR, Netherlands – SURF, New Zealand – MoE).

The framework relies on a service-oriented approach that promotes the creation and reuse of software services that can be used by different applications in different contexts. As shown in Fig. 6 the e-Framework is composed by the following components [18]:

- **Service genre:** a generic or abstract service expressed in terms of behaviours (e.g. authenticate, harvest, search). A Service Genre does not specify how a service works; rather it only specifies what a service should do;
- **Service expression:** a realisation of a single service genre by specification of exact interfaces and standards used. Specifications and Standards (e.g. IMS Metadata, LOM) used by Service Expressions are not defined by the e-Framework;
- **Service Usage Model:** A model of the needs, requirements, workflows, management policies and processes within a domain.

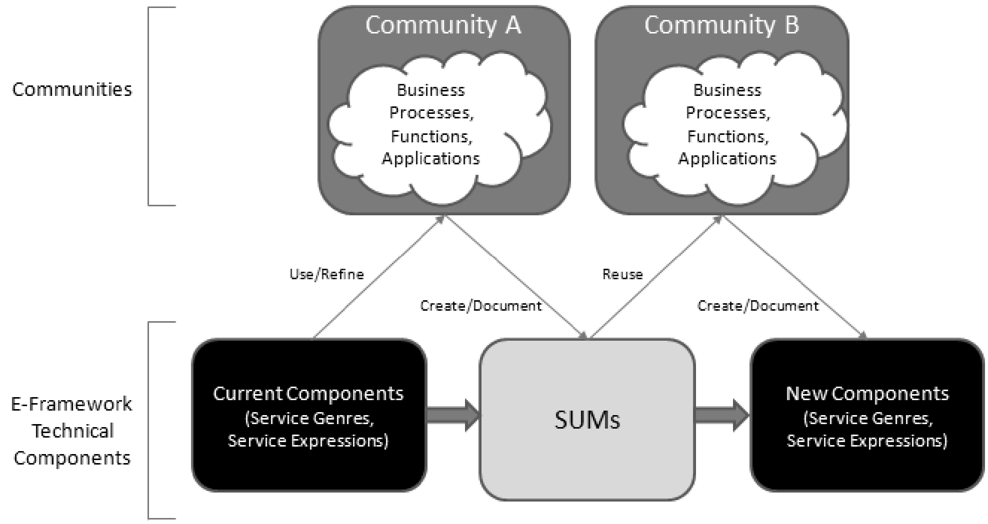

Figure 6 – e-Framework.

All of the e-Framework components are described in template documents, which can be found on the e-Framework website. The e-Framework is currently the target of several updates through the large community of programmers who use the project wiki to submit new contributions.

4 COMPARASION OF ELEARNING FRAMEWORKS

In the last decade several initiatives, commonly named eLearning frameworks, appeared to provide flexible learning environments. In the previous section we detail their overall architecture and main characteristics and divided them in two groups: abstract and concrete frameworks. The Fig.7 traces the evolution of these initiatives based on the previous grouping.

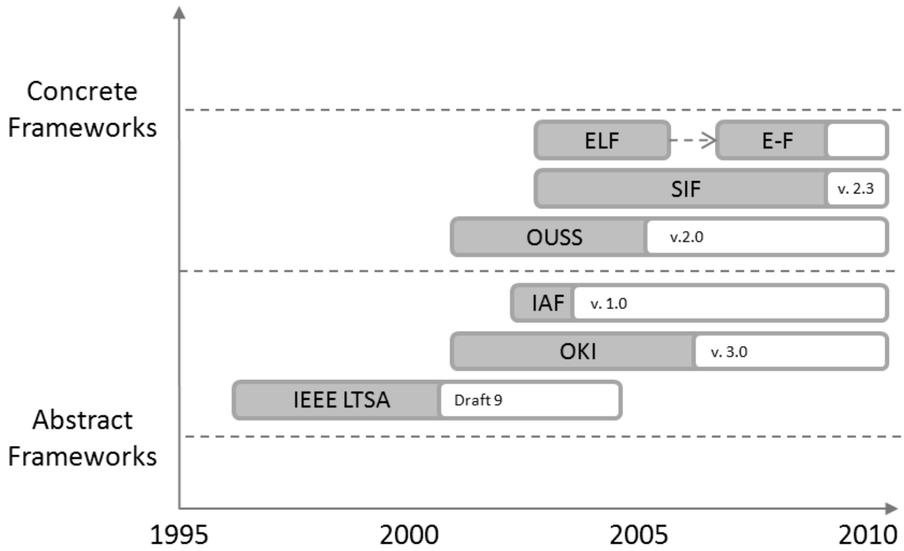

Figure 7 – Evolution of eLearning Frameworks.

The previous figure suggests that, in the last decade, the trend is the appearance of the concrete frameworks rather than abstract frameworks. It is worth noting that none of the concrete frameworks we mentioned actually implement artifacts. At most, these projects include user contributed components, which can be integrated in artifacts for systems using the framework, but are not part of the framework itself.

In the following subsections we compare all these frameworks regarding: architectural models, adopted standards, user groups, impact and maturity.

4.1 Architectural models

The studied frameworks adopt different architectural models. Table 1 lists those architectural models and main concepts used by these frameworks.

Table 1 – eLearning Frameworks architecture.

	LTSA	**OKI**	**IAF**	**OUSS**	**SIF**	**e-F**
Model	Layered *	Layered	Layered	Flat	Flat *	Layered
Main concepts	Processes Stores Flows	Application Educational Services Common services Infrastructure	Application Application Services Common services Infrastructure	Foundation Extension	Applications SIF Agents Zone Integration Server	Service Genres Service Expressions SUMs
Service-Oriented	Yes	Yes	Yes	Yes	Yes	Yes

Analysing Table 1 we conclude that all frameworks adhere to a service-oriented approach. Most of them use the layered architectural model. In this model components communicate only with components in the neighbouring layers. In particular, the LTSA has five layers in its architecture, but only one layer (system components) is normative. In the flat model there is no restriction to the communication among components. The SIF framework is a special case in applying this model since it uses a central component (ZIS) that orchestrate all the communication between applications. These frameworks use different main concepts to present their inner structure. OKI and IAF are an exception since they share their main concepts, which is probably due to the fact that these projects are cooperating [13].

4.2 Adopted Standards

The current frameworks rely on open standards for information exchange and component integration. The next table reviews the adopted standards by these frameworks.

Table 2 – eLearning Frameworks adopted standards.

	LTSA	OKI	IAF	OUSS	SIF	e-F
Content format	-	-	IMS CP SCORM	-	SCORM	IMS CP, SCORM
Metadata	LOM	LOM	LOM	LOM	LOM	DC, LOM
Service Description	WSDL	WSDL	WSDL	WSDL	WSDL	WSDL
Web Service	SOAP	SOAP	SOAP, REST	SOAP	SOAP, REST	SOAP, REST
Language Bindings	-	JAVA, PHP, MS .NET, C#	JAVA	JAVA	JAVA	JAVA

Table 2 shows that certain standards are common to almost all frameworks. For instance, LOM for metadata content, WSDL for service description, SOAP for web service and Java for language binding are common to all frameworks.

4.3 User Groups

The studied frameworks provide an infrastructure for different types of users and have in mind different types of applications. Table 3 lists its main users.

Table 3 – eLearning Frameworks User Groups.

	LTSA	OKI	IAF	OUSS	SIF	E-F
Framework users	Educational software vendors	Educational software vendors	IMS Members	Educational software vendors	Educational software vendors	Educational software vendors
eLearning system end users	Higher Education	Higher Education	Higher Education	Higher Education	K-12	Higher Education and Researchers

From the analysis of Table 3 we notice that educational software vendors are the most common framework users, with the exception of IAF. IMS uses the framework to develop internal specifications (e.g. IMS Enterprise Services Specification). Regarding eLearning systems end users, the higher education sector is the most targeted. As examples of projects in this sector we have:

OKI: Stellar (MIT), CourseWork (Stanford University) and CARET (Univ.Cambridge);

E-Framework: Federated Repositories for Education (FRED), the Learning Object Repository Network (LORN) and the Advanced Distributed Learning (ADL) Prototype Architecture;

SIF: Birmingham Local Authority, Washington School Information Processing Cooperative and Department of Education Tasmania;

OUSS: currently implemented in several universities in Germany and Mexico such as the Bielefeld University Faculty of Sociology, in Germany.

4.4 Impact and maturity

In this study we made an effort to measure the impact of the frameworks in the eLearning context. Although relatively recent, these initiatives have been growing with the contribution of educational institutions and communities of developers. Table 4 compares the studied frameworks on a set of parameters measuring their impact and maturity.

Table 4 – eLearning Frameworks impact and maturity.

	LTSA	OKI	IAF	OUSS	SIF	e-F
Creation date	1996	2001	2003	2001	2003	2007
First version date	Draft 1 (1996)	V1.0 (2003)	V1.0 (2003)	V1.0 2001	V1.0 (2003)	-
Last version date	Draft 9 (2001)	V3.0 (2006)	V1.0 (2003)	V2.0 2005	V2.3 (2009)	-
Number of cited projects	-	3	-	11	37	4
Accepts contributions	Inactive	Yes	Yes	Yes	Yes	Yes

Table 4 shows a very low update frequency (e.g. IAF, OUSS) for several initiatives and one of them is already inactive (LTSA). The frameworks with the most recent updates are the E-Framework and SIF. In the case of the E-Framework, it has been receiving great amount of input from the eLearning community. On the other hand, SIF is the most widely used framework with 37 cited projects in the project web site.

5 CONCLUSION AND FUTURE WORK

In this paper we presented an introductory survey of eLearning Frameworks. These frameworks address interoperability issues among eLearning systems. We divided them in two groups - abstract and concrete frameworks - and detailed their overall architecture and main characteristics. To fully describe these initiatives we also compared them regarding a set of predefined criteria such as: architectural model, adopted standards, user groups, impact and maturity.

The main contribution of this work is the comparative study of the existent eLearning frameworks. This study is part of an effort to select a framework on which to base the development of eLearning systems integrating heterogeneous components. It may prove useful to other persons or organizations facing a similar decision.

We found E-F and SIF to be the most promising frameworks in our study since they are the most active projects, both with a large number of implementations worldwide. However, we do not feel comfortable to choose one of them yet. In order to understand deeply the internals of these frameworks we plan to contribute to both of them. On the E-F we can contribute to the framework itself by proposing new service genres, service expressions and SUMs. We plan to propose new service descriptions related to non-trivial automatic evaluation. On SIF we cannot make this type of contribution to the abstract framework. However, we can contribute with new agents and we plan to adapt a number of existing systems, such as learning objects repositories and programming problem evaluators, to this framework.

References

[1] Girardi, R.: Framework para coordenação e mediação de Web Services modelados como Learning Objects para ambientes de aprendizado na Web (2004).

[2] Dagger, D., O'Connor, A., Lawless, S., Walsh, E., Wade, V.: Service Oriented eLearning Platforms: From Monolithic Systems to Flexible Services (2007).

[3] C. Smythe, “IMS Abstract Framework - A review", IMS Global Learning Consortium, Inc. 2003.

[4] S. Wilson, K. Blinco, D. Rehak, “An e-Learning Framework” - Paper prepared on behalf of DEST (Australia), JISC-CETIS (UK), and Industry Canada, July 2004.

[5] IMS CC Specification, Version 1.0 Final Specification: http://www.imsglobal.org/cc/index.html.

[6] SCORM specification, URL: http://www.adlnet.gov/Pages/Default.aspx.

[7] Markiewicz, M., Lucena, C. “Object oriented framework development”, ACM, 2001.

[8] Wilson. S, Blinco, K. Rehak, D (July 2004) Service-Oriented Frameworks: Modelling the infrastructure for the next generation of e-learning systems.

[9] Official website of IEEE LTSA: http://ltsc.ieee.org/wg1/.

[10] Official website of OKI: http://www.okiproject.org/.

[11] Java binding of the OSIDs: http://sourceforge.net/projects/okiproject/.

[12] Official website of IAF: http://www.imsglobal.org/af.

[13] IMS AF White Paper: http://www.imsglobal.org/af/afv1p0/imsafwhitepaperv1p0.html.

[14] Official website of OpenUSS: http://openuss.sourceforge.net.

[15] Official website of SIFA: http://www.sifinfo.org/.

[16] SIF Members: http://www.sifassociation.org/us/search.asp.

[17] Official website of e-Framework for Education and Reseach: http://www.e-framework.org.

[18] e-Framework Technical Walk-through: http://www.e-framework.org/Portals/9/docs/e-Framework%20technical%20walk-through%20v1.1.pdf.