Building Robust E-learning Software Systems Using Web Technologies

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Building a robust e-learning software platform represents a major challenge for both the project manager and the development team. Since functionalities of these software systems improves and grows by the day, several aspects must be taken into consideration – e.g. workflows, use-casesor alternative scenarios – in order to create a well standardized and fully functional integrated learning management system. The paper will focus on a model of implementation for an e-learning software system, analyzing its features, its functional mechanisms as well as exemplifying an implementation algorithm. A list of some of the mostly used web technologies (both server-side and client-side) will be analyzed and a discussion over major security leaks of web applicationswill also be put in discussion.
Keywords: *E-learning, E-testing, Web Technology, Software System, Web Platform*

1 Introduction

The incredible growth of the Internet in the mid 90's allowed software developers to migrate from desktop development to a newly created branch, web development, allowing World Wide Web to become the homeground of programmers who wanted more than desktop programming. What started up as static web, with HTML as a base markup language, provided extremely large potential of expanding, and, as Darcy DiNucci notices in 1999, „The Web we know now [...] is only an embryo of the Web to come" [1]. The early 2000's represented the transition from static to dynamic, whereas the mid 2000's meant the fully growth of the WWW, starting the era of Web 2.0, an era where the main keyword would become ‚interaction' [2].

In this context, e-learning software systems started to appear in order to provide support for both teachers and students in their educational process. This particular class of software systems became more and more powerful and sophisticated by the day, helping and improving educational programs around the world, therefore many authors have discussed matters like semantic web, ontology or learning management systems. These rather generic terms defined, in the last years of research, a solid ground for designing complex and robust e-learning applications. While Dagoberto Castellanos-Nieves states that „the Semantic Web aims at adding semantic information to web contents in order to create an environment in which software agents will be capable of doing tasks efficiently" [3], LMSs are defined as „powerful tools that help in [...] daily teaching and learning activities" [4], whereas ontologies have a rather ambiguous definition, because „there are many methodologies for building ontologies [...] but none of them can be considered standard" [5].

Under these circumstances, the paper seeks to provide a parallel view on the most common web technologies that can be used in e-learning software systems' implementation. What we want to achieve in this paper is not necessarily a matter of quantity but one of quality, providing a series of possible implementation technologies, along with a short description.

2 Web Technologies

E-learning applications, as well as any other web application, can be implemented in various ways. Depending on the tasks the application needs to execute and on the developer's experience, an e-learning software system can be build using different web-based technologies.

Considering the fact that each technology has its strong and weak parts, it remains to the programmer's choice which one to use in the

development of its software platform. This section will present some of the most common technologies used to implement web applications, attempting to create a high-level overview of these technologies.

2.1 Server-side technologies and / or programming languages

The server-side technologies refer to scripting where a client generates a request to a server, the server analyzes this request and generates a response back to the client. The process is executed on the server and the response returns as HTML code to the client (the web browser). They are mostly preferred by developers due to ease of integration within mark-up language and because of their capability to generate dynamic HTML. Some of the most popular server-side technologies will be listed below (Table 1).

Table 1. Server-side web technologies

Technology	Short Description
PHP	Since its release, in 1994, PHP (the acronym for Personal Home Page) became very popular due to its ease of nesting into HTML code, but started to fully expand since its fourth release, when Zeev Suraski and Andi Gutmans rewrote the PHP engine under the acronym Zend [6]
ASP	The acronym stands for Active Server Pages and has been developed by Microsoft as a response to the open-source technology and rapid expansion of the PHP language; it can easily be nested in HTML code, and represents one of the best precursors of Web 2.0
JSP	Similar to ASP, its acronym stands for Java Server Pages, but this would be the only resemblance between the two technologies; JSP is a part of the Java Enterprise Edition (Java EE) and the .jsp files can dynamically generate HTML, XML or other types of documents [7], as well as Java Servlets (the Java class type that responds to HTTP request)
Python	Is an interpreted, general purpose high-level programming language, whose design emphasizes code reliability [14]. What Python offers is a fully dynamic type system and automatic memory management, therefore often being used as scripting language.
ASP.NET	The successor of ASP, ASP.NET has been developed by Microsoft as a web application development framework; offering OOP (Object Oriented Programming) support through its XML-based components, ASP.NET runs compiled code, increasing the speed of execution, separates HTML code from scripting code and supports over 20 programming languages (even though Visual Basic and C# are mostly used)

A research proposing a quick exemplification of the classic „Hello World" program implementation using the 5 technologies above has been made. After studying its results (Appendix is available upon request), as well as [14], we can set a few criteria to classify these technologies (Table 2).

Table 2. Server-side web technologies comparison

Criteria	PHP	ASP	JSP	Python	ASP.NET
Code length*	medium	medium	medium	short	long
Cost	free	free	free	free	free
License	PHP license	Microsoft	Oracle	Phython	Microsoft
Syntax	C-like	Varies	Java-like	C-like	Varies
API	PHP Manual	MSDN	Java APIs	Python	MSDN

				Reference	
Intended Use	Web, Server-side	Application, Web	Application, Web	General, Application, Scripting, Web	Application, Web
Standardized	No	Yes	Yes	No	Yes
Comments	Useful when implementing custom - designed tools into a web application	Useful when a web application requires a high level of interaction with its users	Useful in custom – designed web applications which require both interaction and customization	Useful when a web application requires a high level of interaction with its users	Useful when a web application requires a high level of interaction with its users

* The criteria depends on the functionality of the program. Here, we refer only to the „Hello World" implementation example.

2.2 Client-side technologies

Opposed to server-side technologies, client-side technologies are the ones that generate the events directly on the client application (usually, the web browser), in order to cut out the time needed for the server's interrogation and response delay and, most important, to create visual an functional effects similar to desktop applications, for an excellent browsing experience to the user. The resemblance to desktop applications is quality in ease and use while the difference comes from the mobility and accessibility [8]. Therefore, RIAs (Rich Internet Applications) have emerged in the last years, providing developers a large set of tools to use (Table 3).

Table 3. Client-side web technologies

Technology	Short Description
JavaScript	As its name states, JavaScript has been originally developed to have a Java look, but a less difficult syntax; it is commonly used in client-side scripting, even though it can be used on server side also; as an empirical definition, JavaScript is the assembler language of the web [...] but one does not want to be exposed to it [9].
AJAX	Asynchronous JavaScript and XML, AJAX, is, probably, the most spectacular technology on client-side scripting; because the requests are called in the background of the user-interface, the effect of a non-freezing window creates an excellent browsing experience for the user; because several different AJAX libraries are available for developers (e.g. YUI, jQuery, MooTools), this technology is continuously improving and providing better functionalities
Adobe Flash	The Flash technology allows the manipulation of media files (audio & video), and it runs on the client machines through a plug-in, the Adobe Flash Player; the scripting language it uses is ActionScript which is similar to JavaScript
Adobe Flex	Flex is a Flash-based collection of technologies used for development of RIAs [7]
Java applets	A Java applet is a program usually written in Java that executes on the client machine, running either through a browser plug-in, using Java Virtual Machine (JVM) or in Sun's AppletViewer, a stand-alone tool for testing applets [14]

A second research has been made presenting the same classic „Hello World" implementation example, this time in client-side technologies development (an Appendix is available upon request). Applying the same procedure as in paragraph 2.1, we have obtained the following comparative results (Table 4):

Table 4. Client-side web technologies comparison

Criteria	JavaScript	AJAX	Adobe Flash	Adobe Flex	Java Applets
Code length*	medium	long	medium	long	medium
Cost	free	free	licensed	licensed	free
License	Depending on js library	Depending on AJAX library	Adobe Systems	Adobe Systems	Oracle
Syntax	Java-based	JavaScript-based	JavaScript-based	JavaScript-based	JavaScript-based
API	Depending on js library	Depending on AJAX library	On vendor website	On vendor website	On owner website
Intended Use	Web, Client-side	Web, Client-side	Web, Client-side	Web, Client-side	Applications, Web, Client-side
Standardized	Yes	-	-	-	Yes
Comments	Suitable for web application which don't require much interactivity between user and browser	Suitable for applications that need to allow users complete browsing interaction, without delays	Suitable for web applications that need to play or embed multimedia files (audio / video)	Suitable for applications that need to allow users complete browsing interaction, without delays	Suitable for web applications that require both interactivity and functionality

* The criteria depends on the functionality of the program. Here, we refer only to the „Hello World" implementation example.

Regarding Table 3, we must point out that all client-side technologies listed above have a solid ground in pure JavaScript. Since web has rapidly evolved, it came natural to JavaScript to evolve, grow and expand into newer and better technologies, AJAX, Flash or Flex being living proofs that, one way or another, they are JavaScript's descendants.

3 E-learning web applications

3.1 Overview

Software platforms for computer-assisted learning and testing represent a special class of web applications, mainly due to the different possible ways of development, integration and implementation. Depending on to whom it is addressed, an e-learning software application needs to reach some objectives. Even though various tools are available for evaluation, testing or learning over the Internet, a standardization has not yet been defined in this research area, although the above technologies are capable of developing modular platforms, easily to improve, easily to manipulate and that creates easy access to data, reports and graphical results [2].

A current trend in computer-aided learning and testing processes is data standardization for this type of software systems. Given the direction of standardization based on metadata, the format in which the questions will be integrated into the system must be clearly defined. Thus, they can be of various types (with short, single or multiple answer, with free answer, with adding item answer and so on) and raises two issues - how will the questions be included into the application and which will be the method or algorithm through whom they will be added into the evaluation tests. Regarding the first problem, research is conducted in the field of automation for the training process (for example, linking the taught material with the assessed one through semantic networks). Regarding the tests generation mechanism, there have been created linear, dynamic or adaptive test generating algorithms

(iteratively dependent on the knowledge of the assessed person [10]).
In addition, the use of semantic web has been more and more often put in discussion in recent research, and, by adding metadata inside web pages, these would become easier to interpret by browsers, allowing the application to become more efficient. This type of strength is the one needed by e-learning applications to become powerful educational tools, providing, besides functionality, quick and pertinent just-in-time educational processes.
A key role in semantic web is played by ontologies. Ontologies are shareable and reusable domain definition used by the e-learning system in the educational process. They can provide important semantic specification over a domain, the combination of semantic web and ontologies providing automatic feedback over the learning methods [3]. Standards like LOM (Learning Object Metadata), SCORM (Sharable Content Object Reference Model) or Learning Design have not yet agreed on how metadata should or must be implemented inside an e-learning application, but they all follow approximately the same pattern: using metadata to allow the retrieval of learning objects and it is only a matter of time until the big picture will be put together and become available to us.

3.2 Classic assessment vs. computer aided assessment

Without an in depth analysis over the advantages and disadvantages of the two assessment methods, we would like to list a few important advantages and disadvantages of using the computer in educational processes (Table 5).

Table 5. Advantages and disadvantages of computer aided education

Advantages	**Disadvantages**
- high objectivity - teaching optimization - dynamically tracking the subject's behavior - automatic result saving - reducing the examination stress - resource saving (e.g. pens, paper) - technological flexibility	- high implementation costs - the need for skilled psychologists (for tracking the subject's behavior and / or educational trace) - potentially bad impact over the subjects - limitations regarding spontaneity and expressiveness of the subjects - hardware limitations

In 1993, A.D. Mead and F. Drasgow [11] stated that, regarding computer-based psychological assessment, there are two kind of tasks that may be taken into consideration: either specially created for online assessment tasks, either adapted versions of classic tasks for computer-aided assessment. Their study revealed the results presented in Table 6:

Table 6. Case study: classic vs. computer-aided psychological assessment

Classic assessment	**Computer-aided assessment**
1. higher average percentage of resolved tasks (both correctly and incorrectly) for vocabulary and form matching tasks 2. higher scores in mathematical tests 3. lower scores in general knowledge tests 4. easier time management and control	1. higher average percentage of resolved tasks (both correctly and incorrectly) for mathematical reasoning 2. lower scores in mathematical tests 3. higher scores in general knowledge tests 4. facing time crisis and, usually, the impossibility of returning to past items 5. significant differences between item display mode

Analyzing Table 6, we can synthesize important marks over the classic / computer-based assessment: there are significant differences between the two test types,

mostly generated by the task's objectives; the predictive power of the tests is not significantly modifying; the use of computers increases the testing process and helps improving the results of the subjects.

Taking these rather generic results into consideration, a serious issue occurs related to computer-aided assessment design. Online testing may be applied in all three methods of traditional assessment: initial, formative (continuous) and summative (cumulative). Therefore, in classic evaluation, many exams try challenging the student's creativity through essays, case studies, open discussions or others. Due to their characteristics, these types of examinations are rather difficult to objectively evaluate even with classical methods, while implementing an automatic assessment system for them would be really difficult to achieve.

The current method for computer-aided testing is by using online questionnaires. Without a big accent on creativity (except for the open-question fields, which have different percents in a test, related to how important creativity is over exact knowledge), questionnaires allow a high level of objectivity, applicable to any discipline, but might increase the professor's efforts in preparing and introducing the questions and answers into the software platform. Some of the ways to automatically assessment for this type of tests are the quantification of the correct answers from the total number of questions, quantification and penalization of the wrong answers, partial scoring of the answers, partial scoring of the answers and penalization for wrong answers, statistical scoring and others. An online evaluation software system should allow tests to be taken simultaneously or individually by students, each student activating its own exam after completing certain tasks. Nevertheless, security of the software platform must be taken into consideration, blocking the student's access to the platform without a teacher's supervision or permission.

3.3 Model of implementation

In our research, we have developed an e-learning software system for testing and assessment of students. The solution we propose has been developed using PHP as server-side technology and AJAX as client-side scripting and is mainly composed of three major modules: the student module, the administration module and the database structure.

What we needed was a tool that would dynamically generate tests, randomize questions and / or answers, generate instant results and have the capability to save and manipulate the tests' results. Three types of users interact with the application: a master administrator, administrators and students. While the master administrator is a special type of user and has special administrative roles, mostly into assigning admin roles and privileges, the other two are the users that interact most with the software platform and take full benefit of the platform's features.

After logging into the application, the administrator has many different management options, including disciplines, chapters, questions and answers, sections that define the content of the online tests. Besides these sections, tests and exams management sections are different and manage the creation, distribution and manipulation of the online tests.

Fig. 1. The administration module

Inside the Exams Management section, the administrator authorizes the students to take the exam, after they have previously registered through an online form. The authorization algorithm we propose counts the students that have registered, validates the list of students and, with the professor's permission, triggers the exam. If a student is not authorized by the professor, he would immediately be removed from the waiting list. A log file is automatically generated, allowing the teacher to have full control over his admission lists and his taken exams. Figure 1 presents the main interface of the administration module.

On the student module, we have created an algorithm that dynamically memorizes the student's answers, allowing him to browse back and forward through the set of questions. If the test is a random-generated one, each student will have different sets of questions, receiving their mark separately, according to their test. Figure 2 presents the student interface, where some key elements can be identified – the student's name, faculty and year, the time remaining and the set of questions. After completing the test, the student would immediately know his result, due to the marking algorithm we have developed.

3.4 The tests

Regarding the examination process, we have proposed two types of tests: fixed tests and random generated tests. The fixed tests are tests in which the professor decides which questions to include, the order of the questions or the difficulty level of them. Here, creation of a test is set by a database field, „*test_type*", set to 1. The user drags and drops his questions to the newly created test, the application memorizes the questions and their order, being now ready to be delivered to the students.

For the second type of tests, the random generated tests, we have developed a generating algorithm that automatically selects different sets of questions for each student who attend an exam. Also, creating such a test requires following a more complex mechanism through the administration module: first, the professor selects the test's type. Since it is a random test, he would next have two options available: „*Compose*" and „*Generate*".

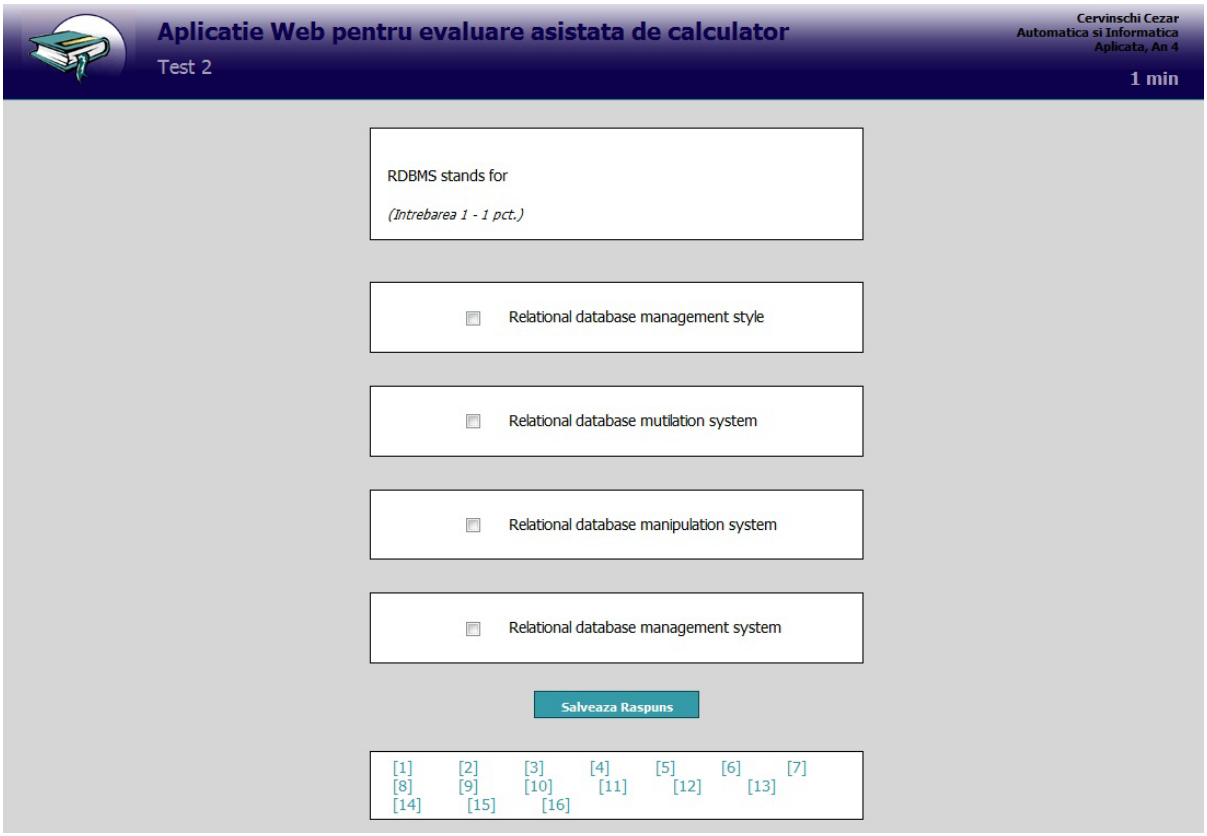

Fig. 2. The student module

The „*Compose*" option sends the user to a list of rules for the newly created test. Without these rules, the test is void, since they decide the subjects of the test, the chapters, the number of questions inside the test and their difficulty level. We have classified our questions with five difficulty levels therefore, for example, the professor might choose 2 questions with difficulty level of 1, 2, 3, 4 and 5, a total of 10 questions equally assigned, from the *Databases* subject, the *Transact SQL* chapter, for example. After saving all sets of rules, the professor must return to the Test Management section and select the „*Generate*" option. This option would require a name and a duration for the new test and automatically transform the random test into a fixed test, correlating the rules set earlier with the new test. Therefore, now, inside the administration panel, the professor would see two tests: the random test first created and the fixed test automatically created after setting up the test's rules and details (this being the test the students would attend to). Now, the random generated test is ready to be delivered to the students. After authorizing all students and starting the exam, the platform generates a log file which contains all the students attending the test and their test's identification number (since they all have different sets of questions). The following listing presents the algorithm that generates the random tests and mixes the questions and answers.

```
<?php
// code snippet: Butucea Diana, CervinschiCezar
function generate_random_test (chapter_id, question_number, difficulty)
{
//function requires 3 parameters and returns an array of ids
   //containing the random set of questions defined by the user's rules
status_message_declare;
count_difficulty_level_of_questions;
select_chapters_to_use;
   //chapters are put in correlation with the difficulty level
   if (no_questions)
{
```

```
write_error_log_file;
}
else
{
return_result_number;
}
declare_array_for_questions;
for_each (question_inserted)
{
save_value_in_array;
increment_counter;
}
status_message_set_to_success;
write_succes_log_file;
deliver_questions_to_test;
}

// code snippet: Butucea Diana, CervinschiCezar
function add_and_randomize_answers (question_id)
{
declare_question_id_array;
select_correct_answers_for_each_question;
verify_number_of_correct_answers;
insert_correct_answers_in_answer_options;
validate_insert_correct_answers;
insert_wrong_answers_in_answer_options;
save_question_id_array;
declare_answer_id_array;
insert_answer_ids_previously_saved;
save_answer_id;
randomize_set_of_answers;
rearrange_answer_id_positions;
deliver_answers_to_test;
generate_log_file;
}
?>
```

3.5 The choose of PHP and AJAX YUI library

Strongly related to Chapter 2, this section will provide arguments over using PHP and AJAX as server / client side web technology. Since, as mentioned above, we needed a tool that would dynamically generate and manipulate sets of questions, we started from the idea of creating our own test generating tool. The ease of use in the PHP programming language made our choice over the server-side technology rather simple – we would definitely use PHPas server-side technology. When referring to client-side technologies, things became a bit more complicated. We had to choose between a less secure implementation over a complete interactive implementation. After studying some of the options, we remained at choosing between an AJAX library and Adobe Flex. Some of the available AJAX libraries were jQuery, YUI, MoTools, which were open source, versus Adobe Flex, a licensed framework. Although we have chosen the AJAX YUI library, our choice has not been totally influenced by financial reasons, YUI providing lots of interface elements that we found extremely useful to implement in our software platform (e.g. data tables, tree views, paginators). Positive aspects to confirm our choice have also been speed of response and relatively ease in implementation.

3.6 Future work

Being aware that our work, so far, has not reached its full potential and that we still have lots of aspects to cover in our research, we wish to continue studying the fields of semantic web and ontologies. Since, as previously mentioned, a standardization has not yet been defined in this research area, we hope that our studies would become useful materials for other researchers. Meanwhile, we will also improve and develop the functionalities of our software model, and, in parallel with semantic web, we wish to fulfill some objectives like implementing an e-learning platform that would be used by blind people, implementation of a single sign on mechanism and gradual transition to web 3.0. Our interest would also imply adding new question types, new test types and proposing new implementation algorithms.

4 Security of e-learning web applications

The software vulnerability term has been defined as "*an instance of an error in the specification, development, or configuration of software such that its execution can violate the security policy*" [12]. Following this definition, we state that every software system, especially web-based, can be attacked by hackers with the objective of data retrieval, gaining unauthorized access or simply data loss for companies. CERT [15]

has reported that statements vulnerable to buffer overflows are the cause of 50% of software attacks [13]. In this section we will make a short overview of the most common security leaks, along with ways of minimizing their effect over e-learning platforms.

4.1 Overcoming implementation leaks

Because Internet has become a gigantic source of information and since the 10 listed technologies are, like we already said, only some of the most used ones, it is clearly to any developer that malicious software bounces freely from one user's browser to another. The need for protection is essential, but to be able to protect a web application, a developer must know its security issues.

Periodically, The Open Web Application Security Project (OWASP) releases the top 10 of the most common methods of attack for the previous year [16]. In 2010, the chart has been presented in Figure 3.

Analyzing Figure 3 and putting it in correlation with e-learning software systems, we can firmly state that this type of web application is as vulnerable as any other. Therefore, special precautions must be taken since sensitive data is managed by such an application: use of safe APIs, escaping all un-trusted database scripts, defining a strong set of authentication mechanism, inclusion of a unique hidden token in the HTML body and sending it via POST method, high software quality assurance, periodic updates, encrypting all important data, strong SSL support and many more. By following simple security rules, such as these ones, a server's or an application's safety should overcome the leaks that may occur.

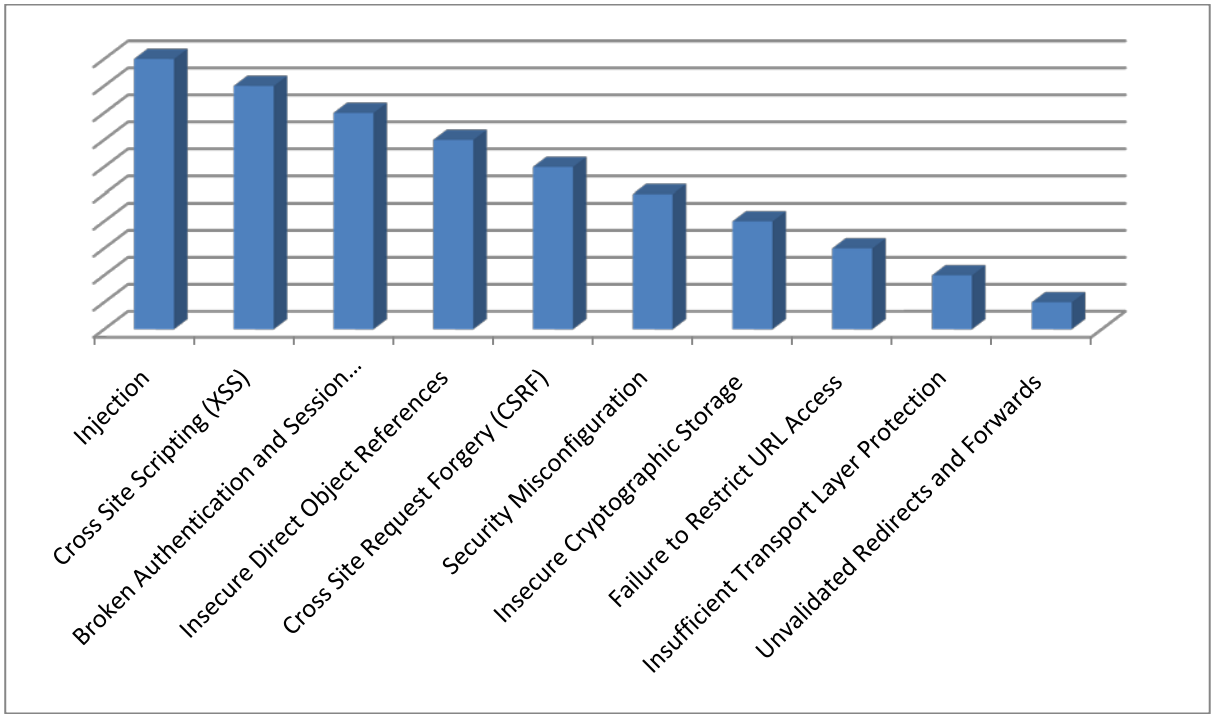

Fig. 3. OWASP 2010 Web Applications Vulnerabilities Top 10

5 Conclusions

The paper presents the implementation model of an e-learning software system, analyzing some of its features, functional mechanisms and implementation algorithms. E-learning software systems represent a special kind of web applications. Because of their functional purpose, they need to be robust and reliable. These two major characteristics are implemented through the web technologies used in the development process. In section 3.5, we have brought a set of arguments to support our decisions regarding the technologies used in this process. Anyway, although the market offers a wide variety of web technologies, in the end it comes to the

developer's decision and work experience which one to use [2]. While server-side technologies represent the basis of the software platform, client-side technologies manage to bring in front the sparks that make the difference between a static, dynamic, aesthetic or functional web application.

The random generated test algorithm is presented to demonstrate our work and confirm that the choices we took were, if not necessarily the best, close to it.

In the paper, we have also presented a survey over some of the most commonly used web technologies inside web application. We have also pointed out a list of characteristics each specific technology has, in Tables 2 and 4, by comparing the classic „Hello world" application implemented with the 10 listed technologies. Our approach wants to create a high level overview over web technologies and tools developers can use in implementing their web applications.

The paper also focuses on security leaks and issues of web applications. So, regarding all the threats a web application is exposed to, both-server side and client-side computing should work together in avoiding any leak that may appear, since e-learning domain requires lots of attention against vicious attacks. Future studies will be made over security issues and the development of a safe transaction mechanism is already in progress, due to the rather personal information that flows through an e-learning software system (or LMS).

From a functional point of view, semantic web represents the future in e-learning, since most of the standards rely on it and since its definition and future research directions point to better knowledge of the domain. The use of ontologies as common, shareable and reusable views [3] of e-learning domains represents only the beginning of the new web-based learning applications and, through our research, we aim and hope to contribute to the research field.

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