

# A web-based learning management system with automatic assessment resources

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**Abstract** - One of the desirable skills for engineering students is the ability of creating and understanding geometric objects. Most of this ability is acquired during elementary and high school courses, but some acquisition are left for undergraduate studies. The introduction of Dynamic Geometry (DG) brings dynamicity to the traditional geometry learning process. Some DG systems present web-based versions, allowing students to use them worldwide through web browsers. By using such systems, students may increase their performance on solving geometric problems, which increase the amount of work to be assessed by teachers or tutors. As a consequence, the delay between the time of submitting the student answer for a problem and its feedback is also increased. Nevertheless, if the learning process is mediated by a web-based learning system, the delay on providing feedback may cause student's disappointment or course abandonment. In this paper we present the free software SAW, a web-based learning management system that incorporates e-learning modules (e-LMs) for specific learning contents, such as geometry or programming. An e-LM is a Java applet that offer resources for client/server communication and may offer resources for problem authoring and automatic assessment.

**Index Terms** – Automatic Assessment, Distance Learning, Learning Management Systems, e-Learning Modules.

## INTRODUCTION

One of the desirable skills for engineering students is the ability of creating and understanding geometric objects. Most of this ability is acquired during elementary and high school courses, but some acquisition are left for undergraduate studies. The introduction of Dynamic Geometry (DG) brings dynamicity to the traditional geometry learning process (with ruler-and-compass). Some DG systems, such as Cabri-Géomètre [3], SketchPad [17], Cinderella [21] and iGeom [4] present web-based versions, allowing students to use them worldwide through a web browser. By using such systems, teachers (tutors) and students (learners) have faced new challenges on their activities. Learners may increase their performance on solving geometric problems, which increase the amount of work to be assessed by tutors. As a consequence, the delay between the student solution for a problem's submission and its feedback is also increased. Nevertheless, if the learning process is mediated by a web-

based learning system, the delay on providing feedback may cause learners' disappointment or course abandonment. This problem could be avoided (or overcome) if the feedback was provided after a short delay. Consequently, the automation of the assessment task could be twofold: it would decrease teachers' workload and the delay between the submission and feedback.

In this paper we present the free software SAW (acronym for Web-based Learning System in Portuguese), a web-based learning management system that incorporates learning modules (e-LMs) for specific learning contents, such as geometry or programming. An e-LM is a Java applet that offer resources for client/server communication and may offer resources for problem authoring and automatic assessment.

The paper is structured as follows: the first section presents an overview about learning management system, followed by a section of some related works, in order to contextualize our work. Then, the SAW system is described followed by the description of some experiences using the system. Finally, we present some conclusions and future work directions.

## LEARNING MANAGEMENT SYSTEMS

Computers and internet related technologies have been used for educational purposes for some time. Existing initiatives such as the development of systems to support the management of teaching and learning activities are spread all over the world, [2][6][25][26][34][35]. There are several denominations for such systems that are usually distinguished through their capabilities of supporting the teaching and learning process. According to Nichani [28], Kaplan-Leiserson [18] and Itmazi et al. [16], the most common denominations are: *Learning Management System* (LMS), *Content Management System* (CMS) and *Learning and Content Management System* (LCMS). In general, an LMS provides resources to manage the student learning process by storing, tracking and manipulating data related to it; a CMS provides resources for the creation, management and publication of web contents, independently of the explored domain content; and an LCMS combines some functionalities of LMS with the CMS ones. LMS and LCMS present overlapping capabilities [10][12] but they differ on their main purposes: LCMS has as its primary use the management of learning content and LMS has the management of learner performance, learning requirements, learning programs and planning [10] as its ones. However, there isn't a unified

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classification of such systems [9]. For instance, if we look for the Moodle System [26] classification in the literature, we will find that some authors, such as Depow [8] and Kennedy [19] classify it as an LMS and other, such as Cole [7], as CMS. In this paper we will adopt the term Learning Management System in a broad sense, meaning that LMS designates any system that provides some management resources for teachers/tutors and for specific contents related to courses.

Nevertheless, independently of the system denomination, the demand for such systems is increasing. Due to the benefits these systems may offer, educational institutions and companies are adopting LMSs to promote distance learning courses and training, as well as to promote regular courses or in-company training [29].

### RELATED WORK

Nowadays, there are several different initiatives to support the teaching and learning process through the WWW. Here we are focused on two of them: the ones related to tools for managing courses, contents and roles of the process, which means, in a broad sense, LMS; and the ones related to tools for increasing interactivity between learners and systems. An important aspect to be considered is how to help tutors on producing materials and taking care of learners activities and actions [23].

When the interactivity is considered, an important field is the use of dynamic geometry [11][21][27][33]. Since the first DG systems (DGS), Cabri [3] and SketchPad [17], several DGS were created. Some of them are implemented in Java, which means that they can be used in web browsers, like Tabulae [11] and Cinderella [21]. Tabulae presents some capabilities that characterize groupware applications [27] in its stand-alone version. Cinderella has a large number of users and presents authoring and automatic assessment resources. However, both of them cannot be fully integrated into an LMS, since they do not provide tools for sending to the server any construction that were did by using them.

### THE SAW LEARNING MANAGEMENT SYSTEM

The development of the SAW was motivated by real needs of undergraduate courses from the Institute of Mathematics and Statistics from the University of São Paulo (IME-USP), Brazil. These needs were related to the increasing use of computational resources to support teaching and learning activities and to the need of managing not even the use of such resources, but also the assessment of the produced material during such activities. In particular, teachers from an undergraduate course were making use of a DG system, and were overloaded with work to assess. A prototype of a web-based LMS [5] was developed to fulfill these needs based on the following requirements: (i) easy incorporation of *e-learning modules* (e-LMs) for specific contents; (ii) communication with a web server through the HTTP protocol; (iii) resources to facilitate the authoring and automatic assessment produced by e-LMs. This prototype was the first version of SAW.

SAW was developed using PHP<sup>3</sup>, Javascript<sup>4</sup> and MySQL<sup>5</sup> database server and it will be sooner available as free software. The main difference between SAW and others LMSs is the ability of incorporating e-LMs to support the teaching and learning process of specific contents providing interactivity in real time, including automatic assessment. The current version of SAW incorporates two e-LMs: the iGeom and the iCG. The iGeom is a DG system with sophisticated functionalities and that is freely available at <http://www.matematica.br/igeom>. The iCG is a prototype of a simple computer simulator with compiling functionalities for a subset of the C language [20]. A third e-LM, the iGraf [31], for teaching/learning calculus, is being developed.

Inside the SAW, the learning content is structured as components and this is made to facilitate reuse. The components are classified as *course*, *lesson*, *topic*, *exercise*, *example* and *text*. A *course* represents a discipline that is part of some curriculum. A *lesson* represents a set of activities related to a subject to be taught in a period of time. A *topic* is an issue that sub-divides the subject of a *lesson*. *Exercises*, *examples* and *texts* are activities that compose a *lesson*.

Components are separated by levels: a *course* is a component of level 1, a *lesson* of level 2, a *topic* of level 3 and *exercises*, *texts* and *examples* are components of level 4. Any component of level  $i$ , for  $i < 4$ , is composed of components of level  $i+1$  and *lessons* can also be composed of a set of components of level 4. Moreover, components may present a dependence relation among them, allowing tutors to establish prerequisites between an activity and a set (or subset) of activities at the same level. For instance, it can be established that in an specific *lesson*, the *exercise*  $e_i$  depends on doing two of the activities  $\{exercise\ e_j, exercise\ e_k, text\ t_{jk}\}$ , meaning that the system will prevent the learner to access *exercise*  $e_i$  before the dependent tasks would be successfully done, e.g. ( $e_j$  and  $t_{jk}$ ) or ( $e_k$  and  $t_{jk}$ ), or ( $e_j$  and  $e_k$ ).

#### 1. The SAW Structure

The SAW architecture follows the client/server paradigm. In the client side there is an HTML interface which provides the use of the system and its associated e-LMs. Since e-LMs are essentially Java applets, their execution is always made in the client. Through the HTML interface the user can login into the system and use it accordingly the access permissions that the role associated with him/her (e.g. *tutor*, *learner*, *administrator* and *tutor-assistant*) has.

The server side presents three layers: the interaction layer, the task layer and the data layer. The interaction layer is responsible for managing and dispatching the client requisitions to the task layer, which is responsible for managing the authoring resources as well as for adapting the status of a component after any modification performed by some of the system users. The tasks results are stored in the database through the data layer. The e-LMs directory stores all the e-LMs and it is accessed through the interaction layer.

<sup>3</sup> <http://www.php.net/>

<sup>4</sup> <http://www.w3c.org/TR/html4/interact/scripts.html>

<sup>5</sup> <http://www.mysql.com>

## II. The SAW e-Learning Modules

The SAW e-Learning Modules (e-LMs) are content specific software components, typically Java applets which provide communication resources through reading HTML tags as applets' parameters and sending data through the POST method<sup>6</sup>. These communication resources are responsible for the interaction between the e-LM and SAW.

An e-LM must be developed to provide support for the teaching and learning process of specific contents, such as geometry, programming and calculus, among others. They may provide resources for authoring and for automatic assessment of problems that will be included in the system as exercises. Examples of e-LMs are iGeom [4], iCG and iGraf. The iCG is a prototype of e-LM for teaching and learning introductory programming and the iGraf is an e-LM for teaching/learning calculus. The iGeom is an e-LM which implements dynamic geometry (DG) for teaching/learning geometry. It possesses functionalities for authoring geometric problems, as well as resources for automatic assessment for their solutions [14]. A brief description of the iGeom e-LM authoring and assessment tool is given next.

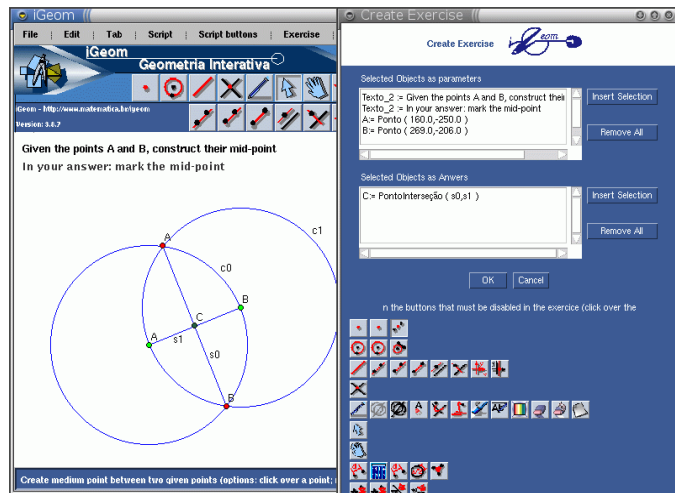


FIGURE 1  
THE IGEOM AUTHORIZING INTERFACE.

The e-LM iGeom authoring interface (Figure 1) is related to its assessment tool. In fact, during the authoring of an exercise, tutors (or content developers) select the “target objects” that will give a known solution for it. Therefore, the tutors’ activity related to the assessment of the exercise is finished whenever he selects the “target objects” of the known solution for an exercise. This known solution is kept hidden into the exercise and, when a learner did his/her solution and click the “send button”, the iGeom assessment tool compare the learner marked objects with the hidden ones. This comparison is made through some metrics defined by all geometric objects from iGeom. Independently of the tutor interference, the e-LM iGeom sends to SAW a variable that indicates if the solution was evaluated as correct or not. The

heuristic that establishes the exercise as correct (or not) uses a combination of metrics computed all over the target objects, in a number of configurations, proportional to the number of free points in the exercise. These configurations are obtained by movements of each free point [15]. A free point is the one which is the basis for moving constructions in DG.

## III. The SAW User’s Roles

The system users may assume the roles of *administrator*, *tutor*, *tutor-assistant* and *learner*.

The *administrator* has permission to introduce/remove e-LMs in the e-LM directory of the system; to include/exclude users into the system; to register users as any of the system roles; to register *courses* in the system; to register *classes* (groups of learners) in a course.

The *tutor* has permission to create/modify any type of the SAW content components (*course*, *lesson*, *topic*, *exercise*, *text*, *example*) that were introduced by him/her into the system; to define which components authored by him/her will be available for other *tutors*; to define prerequisites among components; to create online tests; to define the system or e-LM functionalities that will be available for *learners*; to define the *learners* agenda of tasks; to access and edit *reports* related to the *classes* or *learners* assessment; to post messages at the forum and bulletin board; to put files in the download area and to create instances of cooperative workplaces.

The *tutor-assistant* can have at most all the permissions a *tutor* can have. The permissions are defined by the *tutor* and they are limited to the *courses* the *tutor* is responsible for.

The *learner* has permission to access all *classes* he/she is registered in; to access *lessons* in such *classes* and their related components; to solve *exercises* proposed in such *lessons*; to access the *course* or *class* agenda; to post and answer messages at the forum and bulletin board; to put files at the shared download area from *classes* he/she is registered in; and to work on existent instances of cooperative workplaces.

## IV. The SAW functionalities

The current version of SAW provides the following functionalities: hypertext editor, cooperative workplace, forum, shared download area, upload area, bulletin board, components management tools and assessment tools.

The hypertext editor provided by the system is the MaRTE (*Math Rich Text Editor*), an extension of the RTE (*Rich Text Editor*) [32]. The MaRTE is a *WYSIWYG* (*What You See Is What You Get*) editor [36] that adds to the traditional hypertext editing functionalities (font size, color, format, bold, italics etc; tables editing and insertion; figures alignment and insertion) the ones related to the insertion of math formulae, bibliographic references and e-LMs objects. These characteristics turn it into a powerful interactive hypertext editing tool. In order to achieve the full potential of MaRTE, the server must have a L<sup>A</sup>T<sub>E</sub>X [22] compiler.

The cooperative workplace was conceived to allow the cooperative development of specific subject content in a registered *course* into the system. It is called *Web-media Dictionary (e-Dict)* and it is structured for the development of

<sup>6</sup> [http://www.w3c.org/MarkUp/html-spec/html-spec\\_8.html](http://www.w3c.org/MarkUp/html-spec/html-spec_8.html)

content related to any knowledge area, which can be, *a priori*, divided into sub areas. For instance, in a Geometry course the *tutor* can create an *e-Dict* for Geometry which is subdivided into Descriptive Geometry, Euclidian Geometry, Analytic Geometry and so on. The roles involved in the creation of an *e-Dict* are *tutor* and *learner*. An *e-Dict* can only be created inside a registered *course* by *tutors* from that course. Moreover, an *e-Dict* is composed of *entries* (typically hypertexts edited using MaRTE). The cooperation occurs after the publishing of an *entry*, when *learners*, *tutors* and *tutors-assistants* can post comments about it in order to improve its quality.

The component management tools allow the *tutor* to create linkages between *lessons* and/or between a proposed set of activities. These links can represent prerequisites. For instance, if the link specifies that *lesson A* must be *completed* before the beginning of *lesson B*, the system will prevent the *learner* to begin *lesson B* before *lesson A* would be done. The definition of a *complete lesson* is due to the *tutor* and it is composed of a minimum number of activities that must be done by *learners* during that *lesson* or set of activities. In this case, if the system is using an e-LM with automatic assessment resources, an activity is considered *done* whenever it is delivered and set as “evaluated as correct” by the e-LM. Therefore, learners can follow the teaching and learning path proposed in their own rhythm, without any interference, whenever the e-LM provides assessment resources and tutors establish the path. If the e-LM doesn’t provide such resources, the system marks the activity as *delivered* and the *tutor* (or *tutor assistant*) intervention is needed to analyze if the activity was properly done.

The SAW also provide resources for supporting *tutors* in the assessment task. These resources are composed of *reports* that can refer to a *class* of an specific *course*, or individually, to a *learner*. Moreover, these reports are related to each *lesson* of a *course*. Currently, the system presents three types of reports: the *class report*; the *class summary report* and the *learner report*. The *class report* presents a qualitative analysis of each *learner* from a specific *class* during a given *lesson*. It shows all the SAW components related to that *lesson* and a relation (*learner - component status*) that allows *tutors* to analyze the *learner* performance in each proposed activity for that *lesson*. The *class summary report* presents a quantitative analysis of each *learner* from an specific *class* during a given *lesson*. It shows only the scores of each *learner* for all the activities proposed for that *lesson*. Finally, the *learner report* presents a qualitative analysis, for a given *learner* registered in a given *course*, containing data related to his performance in all the *lessons* from that *course*. Whenever *tutors* allow, *learners* can get a copy of every *exercise* that compose all the *lessons* they were registered in. For those *exercises* that were not submitted to the system, *learners* got just theirs statements. The others are got in their last submission.

#### SAW+iGEOM: APPLYING THE AUTOMATIC ASSESSMENT

The SAW plus the e-LM iGeom (SAW+iGeom) has been used since 2004 in several didactic experiences in

undergraduate courses, summer courses for math teachers and high school.

#### I. Experiences on undergraduate courses

The development of SAW and iGeom has been mainly motivated by an undergraduate course for future math teachers, MAC118, at IME-USP. These course goals were based on “how to teach and promote math learning supported by computer programs” and it was included in the curricula in 1998. Since then, all MAC118 classes take place in a computer lab, usually two learners per computer. The adopted methodology is based on “problem solving” [30] and “learning by doing” [1] techniques, where tutors propose a problem and try to stimulate learners to solve it by themselves, using computer programs as auxiliary tools.

Before the introduction of SAW, in the year of 2004, the main software used in MAC118 was a stand-alone applicative version of iGeom. During 2004, a prototype of SAW with the first version of the e-LM iGeom with authoring and automatic assessment resources was introduced. This version of SAW provided almost all the aforementioned functionalities. From that time on, tutors could prepare lessons composed of texts, examples and exercises, mostly related to an specific topic, in an individualized scheme. Therefore, learners could follow their own rhythm on doing the proposed activities for each lesson, since they could receive immediate feedback related to the exercises that were solved and submitted to the system.

During the years of 2004 and 2005 some case studies were conducted using SAW+iGeom (3 classes - 60 learners each), in an *ad hoc* way, focusing on the system usability and refinement. In 2006 we follow the methodology proposed in [37] to conduct new case studies (3 classes of MAC118) and to better justify our conclusions. Questionnaires were applied at the beginning and at the end of the course and data were collected. The first questionnaire goal was to know the learners familiarity with computers, geometric constructions, LMSs and distance learning. The second questionnaire was based on the Likert scale [24] and its intention was to measure the use of SAW+iGeom and related difficulties.

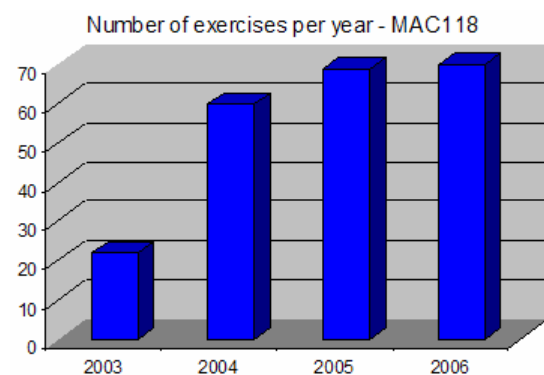


FIGURE 2  
INCREASING THE NUMBER OF SOLVED PROBLEMS

The quantitative analysis related to the number of exercises solved by learners during the course also considered data related to 2003 (teacher’s personal notes), 2004 and 2005

(from the system database). FIGURE 2 shows that in 2003, 20 problems were proposed and this number was increased to 70 in 2006. This was interpreted as a consequence of the use of automatic assessment resources which had encouraged learners in their studies (in 2006, 82% of the learners that answer the second questionnaire think that the use of SAW+iGeom had encouraged them during the course). Also, it reduced the tutor workload and encouraged him/her to introduce preparatory exercises to serve as auxiliary for the solution of the main problem, as well as to leave related exercises as homework.

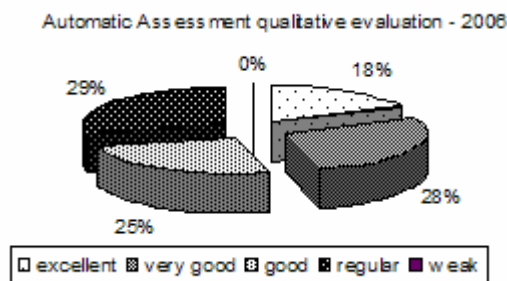


FIGURE 3  
AUTOMATIC ASSESSMENT EVALUATION - MAC118/2006

From learners that had answered the second questionnaire, 80% considered SAW+iGeom *good*, *very good* or *excellent*. Moreover, 71% of them considered the automatic assessment as *good*, *very good* or *excellent* (FIGURE 3).

Observed characteristics presented during the case studies, in a didactic point of view, was the simplification on identifying and spreading out worthy ideas or illustrative mistakes. The SAW+iGeom reports (supporting tools for the assessment task) had allowed tutors to see, in their SAW session, all the learners' solutions set as "evaluated as correct" or the opposite. Therefore, tutors could display an specific solution in a screen for discussing it, to show interesting solutions or common mistakes that were sent by learners. Also, the individualization introduced by SAW+ iGeom shows an increasing participation of learners during classes. Reasons for this improvement could be explained by the individualized environment, where learners could follow their own rhythm of learning, and the immediate feedback provided by the e-LM iGeom automatic assessment of the exercises they had submitted to the system. Therefore, they don't depend on tutors or tutors assistants for going on their learning activities. During 2005 and 2006 tutors work-hours were reduced since they could reuse lessons and exercises that were already stored in the system database.

### II. Experiences on High School Classes

In 2005, the SAW+iGeom was used at Lourenço Castanho School<sup>7</sup>, in 4 high school classes, 30 students each. The introduction of the system and its functionalities was made at the school lab and learners were encouraged to use it while doing homework as well. Before the introduction of SAW+iGeom, geometric problems were solved using ruler

and compass. Therefore, the use of SAW+iGeom was twofold: to introduce the use of DG for solving geometric problems and a system for managing the learners' activities. The experience goal was to compare the learners' performance on solving geometric problems considering quantity and quality of solutions. At the end, it was observed that the use SAW+iGeom improved the solutions quality, mostly because they consolidated the knowledge of some geometric properties through the use of DG and the automatic assessment of their solutions. The amount of solved exercises was increased, probably due to the use of the system functionalities. During 2006, the use of SAW+iGeom was suspended and the learners' performance was decreased when compared to 2005. It will be reintroduced in the second semester of 2007.

### III. Experiences on Summer Courses<sup>8</sup>

During the summer of 2006 and 2007, we use the SAW+iGeom during a 40 hours course for math teachers from fundamental and medium levels (similar to K12). The course was divided in modules, related to trigonometry and polynomials; algorithms and fractals; and mosaics, among others. We could observe the great interest of them on using the system and their desire of using it in their schools. Most of them hadn't had previous experience on using LMS, especially with automatic assessment resources, and classified it as one of the most interesting system functionalities in the questionnaire they filled in at the end of the course.

### CONCLUSIONS AND FUTURE WORK

In this paper we presented the SAW system and its e-LM iGeom. Some experiences on using SAW+iGeom in different contexts (undergraduate courses, high school and summer courses for teachers) were described. All experiences pointed out that the use of automatic assessment resources in an LMS were welcomed, since the instantaneous feedback provided for learners concerning their solutions for geometric problems (without tutors interference) not even had decreased tutors' workload, but also increased the number of exercises they did during the experiences.

As future work, the number of e-LMs in the SAW will be increased, not only related to math issues but to other knowledge areas as well. Also, the Learning Object Metadata (LOM) [13] description for the components created inside the system will be provided, in order to post them in learning objects repositories for promoting their reuse for a large community of teachers and learners.

Ongoing work is the incorporation of the SAW main features and its associated e-LMs functionalities to a new system in the context of the TIDIA-Ae project<sup>9</sup>. TIDIA-Ae involves several brazilian research groups in order to specify, design and implement a comprehensive set of tools for distance learning. These tools are low cost flexible solutions that should have profound social impact as a result of being

<sup>7</sup> [www.lourencocastanho.com.br](http://www.lourencocastanho.com.br)

<sup>8</sup> [www.ime.usp.br/~verao/difusao.html#C17](http://www.ime.usp.br/~verao/difusao.html#C17) (in portuguese)

<sup>9</sup> <http://tidia-ae.incubadora.fapesp.br/portal>

built as Open Source Software tools that can be combined and extended as needed.

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#### REFERENCES

- [1] Aldrich, C., "Learning by Doing: A Comprehensive Guide to Simulations, Computer Games, and Pedagogy in e-Learning and Other Educational Experiences", Pfeiffer, 2005.
- [2] AulaNet – AulaNet System for Distance Learning, <http://www.eduweb.com.br/ingles/> (last visit 03/12/2007)
- [3] Bellemain, F. "Conception, realisation and experimentation of software for teaching geometry: Cabri-géomètre", PhD Thesis, LSD2-IMAG Laboratory", Grenoble, France, 1992.
- [4] Brandão, L.O., "iGeom: a free software for dynamic geometry into the web", *International Conference on Sciences and Mathematics Education*, Rio de Janeiro, Brazil, 2002.
- [5] Brandão, L.O., Isotani, S. and Moura, J. G., "A Plug-in Based Adaptive System: SAAW", *Proceedings of the Intl. Conference on Intelligent Tutoring Systems (ITS'2004)*, Vol. 1, 2004, 791-793.
- [6] ClassWeb: "ClassWeb Open Source Distribution", <http://classweb.ucla.edu> (last visit 03/12/2007).
- [7] Cole, J.R., "Using Moodle: Teaching with the Popular Open Source Course Management System", 1<sup>st</sup> Ed., O'Reilly, 2005.
- [8] Depow, J., "Technical Evaluation Report 25. Open Source Software: Two Learning Management Systems", *The International Review of Research in Open and Distance Learning*, vol. 4, #1, 2003.
- [9] Ellis, R.K., "LCMS Roundup", *Learning Circuits*, <http://www.learningcircuits.org/2001/aug2001/ttools.html> , (last visit 03/12/2007), 2001.
- [10] Greenberg, L. , LMS and LCMS: What's the Difference?, *Learning Circuits*, 2002, available at <http://www.learningcircuits.org/NR/exeres/72E3F68C-4047-4379-8454-2B88C9D38FC5.htm> , (last visit 05/05/2007)
- [11] Guimarães, L.C., Barbastefano, R. and Belfort, E., "Tools for Synchronous Distance Teaching in Geometry", In *Proceedings of the 2nd International Conference on the Teaching of Mathematics (at the undergraduate level)*, Creta, 2002.
- [12] Hall, Brandon, LMS and LCMS demystified, Brandon Hall Research, (last visit 05/02/2007) available at [http://www.brandon-hall.com/free\\_resources/lms\\_and\\_lcms.shtml](http://www.brandon-hall.com/free_resources/lms_and_lcms.shtml)
- [13] IEEE LTSC, "IEEE LTCS Learning Objects Metadata", <http://ieeeltsc.org/wg12LOM/>, (last visit 03/14/2007).
- [14] Isotani, S. and Brandão, L.O., "Analysing constructions in the iGeom: an Approach for Automatic Assessment of Problems", *Proceedings of the Global Congress of Technology and Education*, Santos, Brazil, 2005. (in portuguese).
- [15] Isotani, S. "Developing tools in iGeom: Using the Dynamic Geometry in the Classroom and Distance Learning", MsC Dissertation, Institute of Mathematics and Statistics of the University of São Paulo, 2005. (in portuguese)
- [16] Itmazi, J.A., Megías, M.G., Paderewski, P. and Vela, F.L.G., "A comparison and evaluations of open source learning management systems", In *Proceedings of the IADIS International Conference in Applied Computing*, 80-86, 2005.
- [17] Jackiw, R.N. and Finzer, W.F., "The geometer's sketchpad: programming by geometry", In: *Watch what I do: programming by demonstration*, MIT Press, Cambridge, 293-307, 1993.
- [18] Kaplan-Leiserson, E. "Learning Circuits Glossary", *Learning Circuits*, <http://www.learningcircuits.org> (last visit 03/12/2007).
- [19] Kennedy, D.M., "Student Managed Learning Management Systems: Teachers as Designers", In. Kommers, P. and Richard, G. (Eds) *Proceedings of the World Conference on Educational Multimedia, Hypermedia and Telecommunications 2005*, Montreal, Canada, 3172-3178, 2005.
- [20] Kernighan, B.W. and Ritchie, D.M., "The C Programming Language", Prentice Hall Inc., 2<sup>nd</sup> Ed., 1988.
- [21] Kortenkamp, U., "Foundations of Dynamic Geometry", PhD Thesis, ETH, Institut für Theoretische Informatik, Zurich, 1999.
- [22] Lampion, L., "L<sup>A</sup>T<sub>E</sub>X: a document preparation system", Addison-Wesley, 2<sup>nd</sup> ed., 1994.
- [23] Lucena, C.J.P., Fuks, H., Milidú, R., Laufer, C. and Blois, M., "AulaNet: Helping Teachers to Do Their Homework", In *Multimedia Computer Techniques in Engineering Education Workshop*, 16- 30, 1998.
- [24] Likert, R. A technique for the measurement attitudes, *Archives of Psychology*, 14, 1932.
- [25] Manhattan, "The Manhattan Virtual Classroom", <http://manhattan.sourceforge.net/?Welcome> (last visit 03/12/2007).
- [26] Moodle: "A free, open source course management system for online learning", <http://moodle.org> (last visit 03/12/2007).
- [27] Moraes, T.G. , Santoro, F.M. and Borges, M.R.S., "Tabulae: educational groupware for learning geometry", In *Proceedings of the Fifth IEEE International Conference on Advanced Learning Technologies ICALT'2005*, 750-754, 2005.
- [28] Nichani, M., "LCMS = LMS + CMS – How does this affect the learner? And the instructional designer", <http://usableweb/details/009033.html> , (last visit 03/12/2007), last updated, 2001.
- [29] Pereira, J.C.L and Bax, M.P., "An Introduction to content management", In *Proceedings of the 3<sup>rd</sup> Brazilian Workshop on Competitive Intelligence and Knowledge Management*, 2002.
- [30] Polya, G. "How to solve it", Princeton University Press, 2<sup>nd</sup> Ed., 1957.
- [31] Prado, R. and Brandão, L.O., "iGraf: a proposal of a system for teaching/learning functions through the web", *Anais do III HTEM – História e Tecnologia no Ensino de Matemática*, 2006. (in portuguese).
- [32] Roth, K. "Rich Text Editor", [www.dynamicdrive.com/dynamicindex16/richtexteditor/index.htm](http://www.dynamicdrive.com/dynamicindex16/richtexteditor/index.htm) (last visit 03/11/2007).
- [33] Sinclair, M.P., "Some implications of the results of a case study for the design of pre-constructed, dynamic geometry sketches and accompanying materials", In *Educational Studies in Mathematics*, Springer Netherlands, vol. 52, #03, 289-317, 2003.
- [34] Teleduc: "Distance Learning Environment", <http://teleduc.nied.unicamp.br/teleduc> (last visit 03/11/2007), in portuguese.
- [35] WebCT: "BlackBoard and WebCT", <http://www.blackboard.com> (last visit 03/12/2007).
- [36] WYSISYG, <http://whatis.techtarget.com/> , (last visit 03/11/2007).
- [37] Yin, R.K. "Case Study: planning and methods", Bookman Ed., 2005. (in Portuguese).