

INTERACTIVE LEARNING MODULES IN ENGINEERING EDUCATION AND AS A MOTIVATIONAL TOOL FOR MIDDLE AND HIGH SCHOOL STUDENTS

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Abstract — Engineering courses could benefit from the systematic use of interactive computational resources to support teaching of introductory disciplines. In this paper we present iLM (interactive Learning Modules), which are content specific, multiplatform, software to improve the teaching and learning process. Such components could be easily incorporated to Learning and Content Management Systems, through the implementation of a few methods. Therefore, based on experiments conducted with middle and high school students, we propose the use of iLM as tool for motivating such students to engage in Computer Science, Engineering, and Technology (CSET) careers, as well as physics and mathematics ones. Moreover, we outline the use of existent iLM during introductory CSET courses.

Index Terms — Educational Software, Interactive Learning Module, Interactive Geometry, Learning and Content Management Systems.

INTRODUCTION

Engineering education is usually technology-intensive. It uses many simulation and calculation software systems to support technical domains and projects, which are well suited to advanced studies and professional activities [1]. Engineering courses typically also rely on Internet support – e.g. a website or a Learning and Content Management System (LCMS) that provides learning content and activities for students. In general, teachers and students are used to adopt technology as an educational tool [2].

However, only a few courses succeeded in taking full advantage of computers' potential to facilitate learning. This is true mostly for introductory courses related to elementary sciences (e.g. mathematics and physics) and basic non-applied engineering (e.g. mechanics and electrical circuits). Reasons for that may be related to the quality of educational software, its license costs and other aspects from existing systems concerning usage constraints. Moreover, institutional conservatism promotes resistance to the adoption of new technologies.

Information and Communication Technologies (ICT) provide alternative teaching and learning tools that can be useful when exploring technical education domains that are not studied in many engineering courses [3]. They can be used not only to improve teaching and learning, but also to raise students' motivation. At the high and middle school level, raising students' motivation may also encourage students to follow computer science, engineering, and technology (CSET) careers, as well as physics and mathematics ones.

This paper proposes the use of interactive Learning Modules (iLM), formerly known as e-LM [4], in engineering education and as a motivational support tool for high and middle school students who intend to attend CSET courses as undergraduates. iLM are domain-specific and interactive applets developed as free software for educational purposes. One of the main goals of iLM is to improve traditional classes through the use of computers and the web as assistants that make learning more attractive and interactive [5]. In order to achieve such goal, several iLM were developed and others are under development [6, 7, 8, 9, 11, 12, 13, 14].

The next two sections of this text present overviews and analyses of existing iLM. Subsequent sections discuss the general use of iLM, their potential uses in engineering education courses and results from high and middle school course tests, with particular attention to students' motivation.

OVERVIEW OF iLM

iLM are usually content specific, multiplatform, software components that have features tailored to the specific educational domain each of them address to. They are typically Java applets with enhanced Web communication resources. In order to be classified as iLM, an applet must: (i) be able to read an "activity content" under the HTML tag 'MA_PARAM_proposition'; (ii) implement at least the public method, 'public String getAnswer()', that will get the "student answer".

These communication resources are responsible for the interaction between any iLM and the LCMS. They allow

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students to get an available activity within the system and, after performing it through interaction with the iLM, to send their answer to be registered into the LCMS.

The idea of this concept is to provide a flexible scheme to enrich a Web course, in such a way that the aggregation of any interactive applet became an easy task: just a few methods must be implemented.

An iLM must be developed to provide support to the teaching and learning process of specific contents, such as geometry, counting and programming, among others. Moreover, the possibility of integrating iLM to LCMS is also desirable. Nevertheless, iLM may provide resources for authoring and automatic assessment of activities that will be included in the system, such as exercises or examples.

Currently, there are four iLM available: iGeom, an Interactive Geometry System⁴ (IGS) [9]; iGraf, an interactive mathematical functions' graphs system [10]; iComb, an interactive counting system [11]; and iVProg, a visual educational programming tool [12]. Experimental results of integrating existent iLM with SAW, a LCMS developed by our research group [14, 15, 16], were encouraging. Answers of exercises generated using an iLM could be transferred to SAW and the progress of each student followed, registered and tracked. Moreover, to reach a wider audience, such integration was also brought to Moodle [6], since it is an established LCMS used for thousands of people all over the world⁵.

iLM integrated to LCMS have been used and tested in many courses and some observed benefits of it were documented [14, 15, 16, 17]. A course entirely based on an iLM can be easily created and applied within an LCMS. The project's website⁶ provides a guide for anyone who is interested in using iLM. Next section describes individual features of existing iLM.

ANALYSIS OF EXISTING iLM

Considering the characteristics of iLM, they can be considered as an educational software family that can be used in many different ways. This section describes the main features of existent iLM and outlines how they could be applied in high and middle school and engineering courses.

iGeom – Interactive Geometry on the Internet

Interactive Geometry Systems (IGS) represent a paradigm for teaching geometry [18], since they provide means of performing many different verifications or tests, using only one construction. For example, a user can build the angle bisection, move its points and check its properties in different configurations. This task is very difficult to accomplish using compass and ruler. Some tasks (e.g.

constructing very large circumferences) are also impossible to accomplish without a computer.

Nowadays, there are several available IGS, most of them under commercial licenses [13]. iGeom is a free alternative that provides some unique advantages and features, and it is freely available for download at www.matematica.br/igeom.

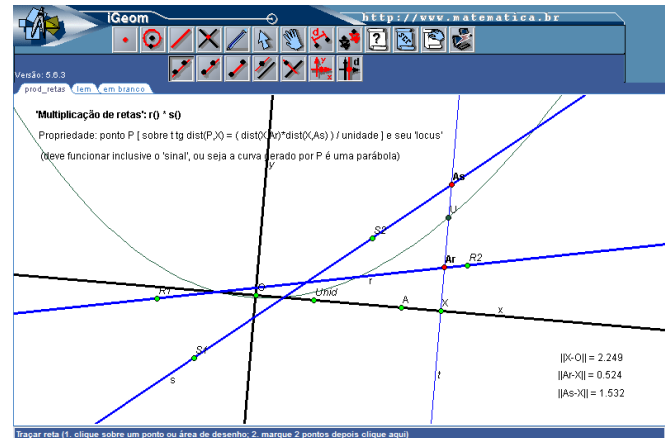


FIGURE. 1
MAIN SCREEN OF iGEOM.

The benefits of using IGS are well-documented [18]. iGeom allows more approaches than general IGS, since it provides features like scripting, recurrence and tracing paths (or *loci*) [14]. Teaching geometry is just part of iGeom possible uses. By using iGeom, it is possible to describe, for example, linear reasoning, introductory programming, recurrent functions, fractals, conics, trigonometry and series. iGeom may, therefore, be applied in many courses not even at middle and high school but also at early college levels, as discussed later in this paper.

Currently, the main features of iGeom are authoring and automatic assessment [8]. The inclusion of intelligent example-tracing tutors in iGeom's exercises [17] is under development.

iGraf – Interactive Graphs on the Internet

iGraf is an applet that allows the creation and manipulation of functions through their graphs and some operations. Figure 2 shows iGraf's main screen. It is freely available for download at www.matematica.br/igraf. Its development began in 2005, and it has evolved into an iLM that presents features for authoring, assessment and tracing reports.

In iGraf, it is possible to write the expression of a function and plot its graph. As the plotting of graphs is done parametrically, they can easily be moved or animated. As integral and differential operations are also permitted, iGraf is also highly recommended for calculus-related courses. In addition, iGraf's allows a range of explanations and

⁴ IGS were formerly known as Dynamic Geometry Systems – DGS.

⁵ <http://www.moodle.org>

⁶ <http://lem.ime.usp.br/imatica/>

explorations that will be detailed in later sections of this paper.

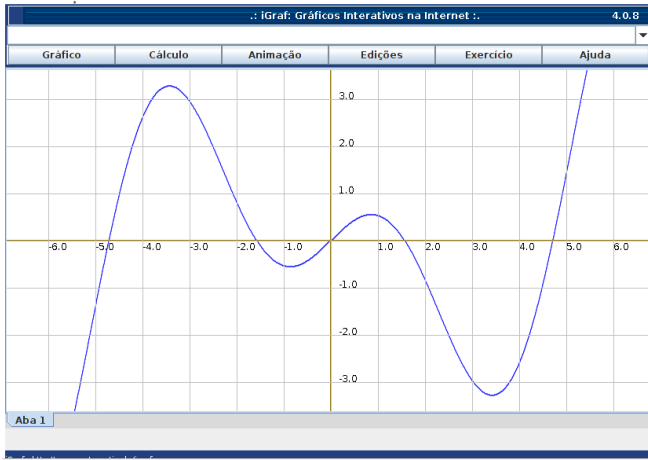


FIGURE. 2
MAIN SCREEN OF iGRAF.

Ongoing efforts to upgrade iGRAF include creating features that will improve function’s expression syntax and automatic exercise checking, in addition to the implementation of numerical calculus methods.

iComb – Interactive Counting

Counting is, like most mathematics issues, a theoretic field that is usually taught with regular pencil and paper [11]. iComb, whose main screen is shown in Figure 3, was created as an Web version of the Combien? system [20]. iComb deals mostly with combination issues and it is freely available for download at www.matematica.br/icombo.

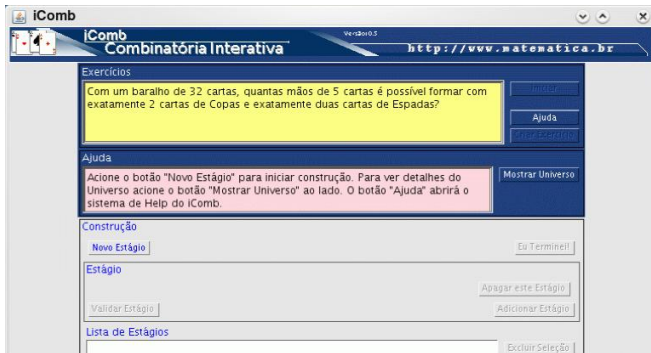


FIGURE. 3
MAIN SCREEN OF iCOMB.

iComb can be used to teach combination through exercises and examples. Exercises are grouped by themes, like decks of cards and soccer players. Once an exercise has been selected, students answer a simple question proposed by iComb: “How many sets of ... are possible to form

given...?” Guided by iComb, students can choose elements from a universe (e.g. cards, soccer players) and get immediate, interactive visual feedback about those elements. Like other iLM, many pedagogical approaches can be used to teaching different levels of basics engineering disciplines – for example, introduction to probability, or high school counting related activities.

iVProg – Visual Programming

Several approaches and systems are used to improve the teaching and learning of introductory programming [21]. One is called visual programming because it requires no (or little) writing of code, instead, computer programs are created by dragging and dropping symbols, for instance [22]. The main advantages of visual programming are that students do not need to care about language-specific syntax and it is easier to spot code errors and focus on algorithms.

iVProg is an iLM that adopts the visual programming approach. As the best of our knowledge, it is the only web-based system that has such characteristics and that is free [12]. Figure 4 shows its main screen. It is freely available for download at www.matematica.br/ivprog.

iVProg can be used to give students programming language-independent knowledge. It can also be used at the beginning of an introductory programming course, before switching to a real programming language. A study to determine whether iVProg is best suited to the former or latter is underway.

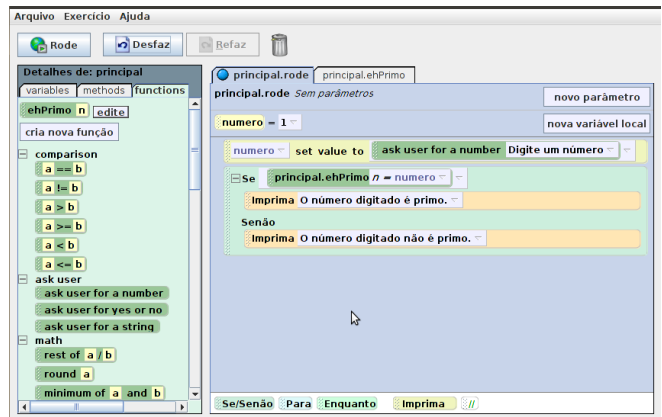


FIGURE. 4
MAIN SCREEN OF iVPROG.

GENERAL USE OF iLM

iLM may run embedded in web pages or integrated to LCMS, but it also may run standalone if a desktop version is provided. Nevertheless, only when they are integrated to an LCMS it is possible to register courses and track student progress in a database.

Currently, two LCMS are compatible with iLM – SAW [15] and Moodle [6]. Whenever iLM are integrated to

aforementioned LCMS, teachers and content providers can use just them to prepare, store and publish content specific educational activities. Such activities are ready to be used by students at the very moment teachers publish them within the LCMS, and their development could be followed by teachers through the report features. Nonetheless, all activities produced can be stored in the system for further use. The creation of a repository for activities or courses that use iLM [7] and a new Moodle core [8] with hierarchical content organization are under development. Figure 5 shows how to use Moodle to add a new iLM activity to a course.

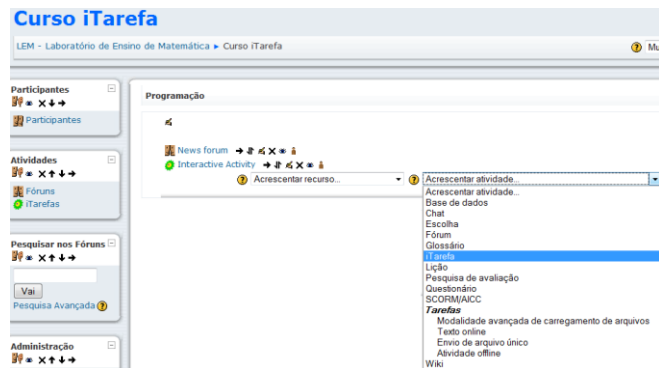


FIGURE 5
HOW TO ADD AN iLM ACTIVITY TO A MOODLE COURSE.

USE OF iLM IN ENGINEERING EDUCATION

In general, engineering courses are preceded by elementary mathematics and physics courses that proceed to basic engineering and, then, to applied and technical engineering courses. During the first part of elementary mathematics and physics courses, there is usually little use of domain-specific software, as such courses take highly theoretical approaches to solving problems. Similar approaches are often taken in basic engineering courses, but at this stage, they are supported by simulations and calculations and, sometimes, educational systems [2]. As courses reach the applied part of their curricula, software systems are frequently used more often – for example, with simulations [1].

The main difficulties of using software systems in engineering education are related to the fact that most of them are primarily intended for professional use. Although student versions exist, license costs and lack of educational features generally interfere with students' and teachers' ability to enjoy their pedagogical benefits.

This section discusses how iLM can act as alternatives to software systems typically used in early engineering courses. It also outlines how iLM can be used in domains where software is not usually used.

Fundamental Education in Mathematics and Physics

In the following, a discussion about the use of iLM in fundamental math and physics is presented. iGeom can be

used to support teaching several topics related to Analytic Geometry, for instance geometric objects' properties, theorems and parametrical equations. In linear algebra, iGeom can serve as a graph viewer for many properties and theorems.

In calculus, iGraf can be used to visualize and test properties of functions, including their behavior, derivatives, integrals, and tangent lines, among others. iGraf can also be used to generate exercises to promote a better understanding about the role of functions parameters and constants and making links between graphs and equations as well.

Introductory courses in probability can use iComb to provide the exploration of fundamental concepts of counting in systematic ways, before moving to more abstract thinking. iComb software may improve students' confidence, as it presents unique ways of exploring subjects that might confuse the average student. iComb also allows students to engage in non-deterministic reasoning and achieve different, correct answers to problems.

iVProg provides an easy way to teach and learn introductory programming given its visual approach.

Future work may allow specific topics in physics and mathematics – e.g. waves, mechanics, electromagnetism, general algebra, differential equations, calculus with two variables – to have their own iLM.

Basic and Applied Engineering Courses

Existing iLM have fewer applications in basic and applied engineering courses than in fundamental engineering courses. Nevertheless, some existing features can be adapted to the needs of basic and applied engineering courses.

iGraf is most useful in engineering courses. It can, for example, show digital functions through its piecewise continuous functions, or different kinds of sine wave for signal analysis and functions that are solution of differential equations. iGeom can also be used as a graph viewer in algorithm related courses.

Future work may allow each engineering field to have its own iLM – pertaining, for example, to materials resistance, computer organization, fluid mechanics, heat transfer, materials science, electrical circuits, electronics, structure projects, and control, among others. The development of such iLM should be made feasible by recognition of their potential benefits to specific domains.

iLM TO IMPROVE STUDENTS' MOTIVATION TO PURSUE ENGINEERING

After several experiments conducted using iLM during different courses and for diverse audiences, we start considering that it could motivate high school students to engage in engineering and related careers. This section reports some experimental results related to this assumption.

All experiments included pre and post questionnaires that were filled by courses' attendees and the systematic use of an iLM (iGeom). The results obtained from experiments

with high school students who use iGeom desktop version [17] and who attend in online courses [6] are summarized as follows: iGeom had increased students' enjoyment concerning the subject they were studying. Students who got better results had, in addition, increased their motivation to learn. Introducing iGeom to a classroom usually increases the number of students who say that they intend to engage related undergraduate courses in the future.

Experiments conducted with undergraduate students of mathematics courses using iVProg [12] showed that student motivation had increased. This suggests that using iVProg in classrooms may reduce evasion from the beginning of CSET courses.

Despite the fact that the results of documented experiments are not directly related to motivation and the intention of engaging undergraduate engineering courses, it is possible to infer that the use of interactive educational software in basic education and in the first year of undergraduate studies can raise students' overall motivation to study CSET courses.

CONCLUSIONS

Experimental results and inferences about them showed that CSET courses can be benefited from the use of iLM twice: during introductory courses such as calculus, statistics, programming, linear algebra, among others; and during high school courses, to motivate students to pursue CSET related careers.

Existent iLM were presented and their use proposed to improve teaching and learning during introductory disciplines of CSET courses.

The paper also suggests that many fields in engineering education would benefit from the development of specific iLM.

ACKNOWLEDGMENT

Danilo L. Dalmon is supported by FAPESP grant 2010/06805-2. Leônidas O. Brandão is partially supported by FAPESP grant 05/60647-1.

REFERENCES

- [1] Balamuralithara, B. B., Woods, P. C., "Virtual laboratories in engineering education: The simulation lab and remote lab", *Computer Applications in Engineering Education*, Vol. 17, No 1, 2009.
- [2] Rothberg, S., Lamb, F., Wallace, A., "Computer Assisted Learning in Engineering Degree Programmes: A Survey at the End of the 20th Century", *International Journal in Engineering Education*, 2001.
- [3] Hentea, M., Shea, M., Pennington, L., "A perspective on fulling the expectations of distance education", *Conference on Information Technology Education*, 2003.
- [4] Moura, J.G., Brandão, L.O., Brandão, A. A. F., "A Web-based Learning Management System with Automatic Assessment Resources", *Proceedings of the 37th Frontiers in Education Conference*, 2007, pp. F2D-1-F2D-6.
- [5] Hara, N., Kling, R., "Student's frustrations with a web-based distance education course". *Journal on the Internet*, Vol 4, No #12, 1999.
- [6] Rodrigues, P. A., Brandão, L. O., Brandão, A. A. F., "Interactive Assignment: a Moodle Component to Enrich the Learning Process", *Proceedings of the 40th Frontiers in Education*, 2010.
- [7] Santa Rosa, E. R. M., Brandão, L. O., "iRCD: Proposta de um novo recurso de Repositório de Conteúdos Digitais Interativos para o Moodle", *XXI Simpósio Brasileiro de Informática na Educação*, 2010.
- [8] do Nascimento, M. G. F., Brandão, L. O., "Novo núcleo para o Moodle: promovendo um modelo hierárquico e compartilhável para disciplinas virtuais e materiais digitais", *XXI Simpósio Brasileiro de Informática na Educação*, 2010.
- [9] Isotani, S., Brandão, L. O., "An Algorithm for Automatic Checking of Exercises in a Dynamic Geometry System: iGeom". *Computers & Education*, Vol. 51, No #3, 2008.
- [10] do Prado, R., Brandão, L.O., "iGraf: Módulo de Aprendizagem para Ensino de Função na Web", *XIV Simpósio Brasileiro de Informática na Educação*, 2006.
- [11] Eisenmann, A. L. K., Brandão, L. O., "iComb: um sistema para o ensino e aprendizagem de combinatória em ambiente Web", *XX Simpósio Brasileiro de Informática na Educação*, 2009.
- [12] Kamiya, R. R., Brandão, L. O., "iVProg - um sistema para introdução à Programação através de um modelo Visual na Internet", *XX Simpósio Brasileiro de Informática na Educação*, 2009.
- [13] Brandão, L. O., Isotani, S., "Uma ferramenta para ensino de Geometria Dinâmica na Internet: iGeom", *IX Workshop sobre Informática na Educação*, 2003.
- [14] Brandão, L. O., Isotani, S., Moura, J. G., "Immersing Dynamic Geometry in Distance Education Systems: iGeom and SAW". *Brazilian Journal on Informatics in Education*, Vol. 14, No 1, 2006.
- [15] Moura, J. G., Brandão, L. O., "Aplicações no SAW - Sistema de Aprendizagem pela Web", *XVI Simpósio Brasileiro de Informática na Educação*, 2005.
- [16] Moura, J.G., Brandão, L.O., Brandão, A. A. F., "A Web-based Learning Management System with Automatic Assessment Resources to Support the Diversity of Learning Rhythms". *XVIII Simpósio Brasileiro de Informática na Educação*, 2007, pp. 462-472.
- [17] Tanbellini, M. J. G. S., Brandão, L. O., "O uso da geometria interativa como facilitador no ensino e aprendizagem de matemática: estudo com duas turmas de sexta série do ensino fundamental", *XVI Workshop Sobre Informática na Escola*, 2010.
- [18] Ruthven, K., Hennessy, S., Deaney, R., "Constructions of dynamic geometry: A study of the interpretative flexibility of educational system in classroom", *Computers and Education*, 2008.
- [19] Dalmon, D. L., Isotani, S., Brandão, L. O., "Melhorando a Geometria Interativa com o uso de Tutores Rastreadores de Padrões: iGeom e CTAT", *XVI Workshop sobre Informática na Educação*, 2010.
- [20] Le Calvez, F., Giroire, H., Duma, J., Tisseau, G., Urtasun, M., "Combien? a Software to Teach Students How to Solve Combinatory Exercises", *Proceedings of Artificial Intelligence in Education*, 2003.
- [21] Burton, P. J., "Teaching Programming in the OOP Era", *ACM Special Interest Group on Computer Science Education Bulletin*, Vol. 35, No #2, 2003.
- [22] Winslow, L. E., "Programming pedagogy - a psychological overview", *ACM Special Interest Group on Computer Science Education Bulletin*, Vol. 28, No #3, 1996.