Catch the Mark: teaching data hiding by gaming

F. Battisti, M. Carli, A. Neri
Dept. of Applied Electronics
Universita' degli Studi Roma TRE
Rome, Italy
Email: fbattisti, carli, neri@uniroma3.it

G. Boato
Information Engineering and Computer Science Dept.
University of Trento
Trento, Italy
Email: boato@disi.unitn.it

***Abstract*—The use of digital media for improving the effectiveness of teaching methodologies in Universities is increasing. In this contribution the experience performed at University of Roma TRE is presented. Since 2005 an online contest is used in the Multimedia class for improving both knowledge and human interaction. This paper shows the competitive-collaborative learning scheme adopted and it reports the feedback received by the students that has been collected by means of a questionnaire. The obtained comments show the effectiveness of the proposed learning scheme.**

***Index Terms*—Competitive learning, computer utilization, data hiding, digital watermarking, engineering education**

I. Introduction

The digital era in which we are living is flooding the human being with technologies significantly different from what was available just a decade ago. Nowadays students life is based on a digital and technological environment. Following this trend, even if with some delays, technology-enhanced learning methodologies have been proposed in several electronics engineering courses as an auxiliary mean for improving the teaching effectiveness in terms of student learning capabilities and interest in the topic. This has become possible due to the availability of computer-equipped classrooms and pervasive networking technologies (wireless networking).

In this contribution the results obtained through an international contest among students, called *Catch the Mark* (CTM), are presented. The context has been practicing since 2005 for teaching digital information security. It is based on a double role concept: as defender, the students teams design and implement their watermarking method and as opponent, they try to remove or destroy the watermark inserted by other groups.

The motivation behind this competition is in the belief that a direct experience in understanding strengths and vulnerabilities of the designed algorithms may increase the topic understanding and learning. Moreover, having the students also to act as attackers forces them to better analyze the drawbacks and weaknesses of the developed technology.

From an educational point of view, we based our approach on pedagogic studies:

- the use of a competitive-collaborative learning approach has been studied as learning methodology. Evaluation methods and performance metrics emphasize individual effort and achievement; however when more students are cooperating the overall effectiveness increases, [1]–[7]. The active involvement of students organized in small groups is effective with respect to both the amount of content learned and its retention. Moreover the social interaction improves the individual social skills, self esteem, and tolerance of diversity. The use of this learning scheme has also been addressed by the European Union under various initiatives such as ECOLE [8] or *Leonardo* projects;
- during the enrollment phase of this academic year (2010/2011), the Engineering Faculty of University of Roma TRE, in Roma, Italy, proposed a questionnaire to the future students. The number of collected answers was 976. Among the questions, some of them are strictly related to the motivation behind this paper:
  1) *Do you have a personal computer?* 99% has one or more pc;
  2) *Which communication media would you like to use for receiving teaching information, grants, news, performances..?* 69% would like to use email, 19% prefers SMS, and only 8% selects Social network (Facebook, Twitter, etc.) as preferred information media;
  3) *Would you like to have on-line teaching*

systems? 62% of positive answers.

The questionnaire was submitted to students of age in the range [18-21]. From the collected answers, it results that students are available for using computer based communication systems as channel for receiving/giving didactic information. In fact, almost all of them (81%) are connected through Internet on daily bases. It should be noticed that the social network is preferred only by 8% of students, probably due to the fact that till now these networks have been used mostly for entertainment or for sharing personal information;

- finally, the use of learning by gaming has been demonstrated as an effective system by many authors [9], [10], and [12]. A survey of learning by gaming can be found in [11].

To assess the effectiveness of incorporating CTM into a final-year class of a M.Sc. in Electrical Engineering curriculum, every year a questionnaire was given to the contest participants. Over the years, the number of students and countries involved in the CTM contest has increased. Graduate and Ph.D. student teams from France, Finland, and Romania joined Italian teams composed of students from the Universities of Trento, Trieste, and Roma TRE. In this contribution the performed experience, and the collected results are shown.

II. Watermarking and the Game

Digital watermarking is a class of techniques, generally adopted for preventing users from removing copyright information. It is based on the insertion of a known information (the mark) into the data to be protected before its distribution. The detection of the presence of the original mark into the document under test, allows the data ownership verification.

The use of the competition as learning approach slightly modifies the teaching methodology. Basically in our class, after the motivation and background theory review, the state-of-the-art methodologies are shown detailing the peculiarities of each solution, their applicability to a particular scenario, their computational complexity, eventual implementation issues, and their advantages and disadvantages. Then the students, organized in groups, are asked to implement the algorithms by themselves and to assess the performances through simulations. The students are not provided with code, to push them to think critically about solutions, and not just to acquire ability in assembling already-available solutions.

Each group has to design and implement its own watermarking method providing the watermark detection code before the game. During the competition each team has to mark a set of images with the developed method, and to perform attacks against the other teams' hiding systems in order to remove their watermarks. All data are uploaded online where all other groups can download them, try to destroy the inserted marks and then upload attacked versions. The effectiveness of each proposed solution is graded with respect to its ability to resist to the attacks during the competition.

III. The Contest

The *Catch the Mark* contest is a one-day competition, usually lasting four or five hours. Before the competition day, each team is trained in the rules. The public advertisement of the game, posted one month before the day on the Internet (see http://www.comlab.uniroma3.it/ctm_rules_10.html), is summarized here:

- *Competition Goals*: students have to form groups of no more than four people. Each group has to implement a technique for embedding and detecting the watermark. This technique has to comply with the requirements of invisibility, robustness, and capacity.
- *Gradings*: each group's activity is evaluated by considering:
  - the quality of their watermarked images (watermark imperceptibility);
  - the ability of their embedded watermark to resist the other groups' attacks (watermark robustness);
  - the number of the other groups' images from which it has succeeded in removing the watermark (activity).

In the first *watermarking* phase (usually lasting for one hour), teams mark the images eventually tuning their algorithms parameters. Then, the uploaded watermarked images become available to all other groups. Such images have to satisfy the fundamental imperceptibility and robustness requirements. As stated above, grading takes into account the quality of the watermarked data and the robustness of the embedding procedure used.

During the following *attack* phase (usually lasting for two hours) teams try to remove the watermark while keeping high the image quality. At the end of each phase, the groups are required to upload their watermarked images to the web site.

At the end of the competition all groups upload the images from which they have succeeded in removing the watermark (the number of attacked groups is highly dependent upon the single group activity and/or on the robustness of the involved data hiding methods). The tight schedule of the game forces the students to collaborate, thus reducing the possibility of unbalanced work within the groups.

IV. Context results evaluation

To understand the effectiveness of the game, beside the final student course evaluation, a questionnaire has been proposed to the students. The Italian participants were asked to answer the questionnaire at the end of the course. Their age was from 23 to 28. Although

TABLE I
GENERAL LEARNING SECTION OF THE QUESTIONNAIRE.

During the training classes:	Answer (min-max)	Mean score	Variance
Did you use the opportunity to interact with teacher for more details about the topic?	(1-5)	4.31	0.58
Could you test/apply what you learned during lectures?	(1-5)	4.25	0.97
Did you have enough information on the topic?	(1-5)	4.25	0.88
Did you succeed in creating study groups?	(1-5)	4.31	0.86

optional, a high percentage of students completed the survey.

One of the sections of the questionnaire, reported in Table I, is related to the general learning context: information on the availability of learning materials (if sufficient or not), resources used during the course (documents, study units, tutoring, peer to peer exchange, university library materials, downloadable presentations, and software), the level of interaction between teacher and student, opportunities to practice what has been learnt in theory (if sufficient or not), and the possibility of creating peer-groups for study.

The following sections are dedicated to gathering information about students level of involvement in and satisfaction with the course (see Tables II and III). In most questions, the students were asked to associate an evaluation score in the range $[0, 5]$, 1 corresponding to strongly disagree (or completely useless) and 5 to strongly agree (very helpful). In other questions possible answers were *yes/no*, and finally in some cases open answers were requested, to get suggestions, criticism, and feedback from students.

In particular, from the results shown in Table I it can be noticed that the students gave a positive evaluation of the training phase based on the collaborative/competitive approach. In fact, the average score for all questions is greater than 4. Moreover, the opportunity to practice and to interact with the lecturer and their peers was taken advantage of and appreciated by most students.

Table II provides the average for the answers related to evaluation of student involvement in the course. It can be seen that the training for CTM did not significantly increase the amount of time required to prepare for the exam compared to other courses, and the impact on the overall study performances was not significant. Therefore, more than 60% of students were able to prepare for more than one exam. It is worth mentioning that in Italian universities it is common for a student to prepare for more than one exam simultaneously, due to the quarter/semester class scheduling (lessons followed by exams periods). Moreover, the high percentage of students who studied in groups (74%) demonstrates the achievement of one of the goals for this approach.

From the answers to the question about the material used by the students to prepare the exam and the game, some interesting observations can be made. To prepare for the game as well as using the recommended textbooks, students also used lecture slides (available on the Internet for downloading) and in-class notes, books and scientific literature on the topic. This active behavior among students can be considered as one of the positive side effects of the proposed approach.

The overall evaluation of the effectiveness of the method from the point of view of the students was the subject of specific questions in Section 4 of the questionnaire. As illustrated in Table IV, this evaluation was completely positive and the general feeling of the students about this education method can be effectively summarized by the following comment: "*thanks to the game, the interest of students is caught*."

Considering the effort spent by the students in acquiring the theoretical background and the skills on the specific topic, it can be observed that:

- 12% of the methods employed in the competition were an implementation of state-of-the-art methods. All of these were fully explained in the class material both from an algorithmic and an implementation point of view;
- 65% were modifications of existing methods, trying to solve the inefficiencies of those methods (stated during classes), usually obtained by fusing together different approaches;
- 23% were almost completely new. Independent of their effectiveness, this active behavior is one of the main achievements obtained by this teaching scheme.

The students who were not able to attend class sessions and to participate to the game, had to take the final exam as an oral interview. After the exam they were asked about their willingness to attend the new-style class and the interactive game. All of them regretted not being able to attend the class, and they positively encourage the use of similar teaching methods in other classes.

From a comparison of histogram scores obtained in the final exam by students participating in the competition with the histogram of the scores of the students not attending the contest, we noticed that the proposed game approach produces a significant positive difference in competencies and knowledge gained. In particular, the average scores are 29.15 and 23, respectively, for the two groups of students; the scores of the students participating in the game were always higher than those of the other students, revealing a deeper understanding of the course contents. It is important to underline that in Italian universities the scores are in the range [0, 30] with a value of 18 corresponding to the "passed" (D-) grade and 30 corresponding to "excellent" (A+) grade. From the above reported percentages, it can be seen

TABLE II
SECTION 3 OF THE QUESTIONNAIRE TO UNDERSTAND THE STUDENT INVOLVEMENT IN THE COURSE.

Question	Answer range	Result statistics
Average grade in previous exams?	(18-30)	28.8 (average)
Time required to prepare for the exam?	n. months	1.9 (average)
Did you prepare other exams in the same period?	yes/no	62% yes 38% no
Did you study alone or in group?	(alone/others)	26% alone 74% group
Did you use the teacher and assistants "office hours"?	yes/no	55% yes 45% no
If *yes* how many times?	number	4 (average)
What materials did you use for studying?	free answer	—

TABLE III
STUDENT SATISFACTION SECTION OF THE QUESTIONNAIRE.

Question	Answer range	yes	no
Possibility to achieve cross-curricular skills, useful also in other classes?	(yes/no)	90%	10%
Appropriateness of the approach to the subject	(yes/no)	99%	1%
Recommended the course to others colleagues	(yes/no)	100%	0%
Would you like to have the same teaching system in other classes?	(yes/no)	94%	6%

that the goal of pushing students to think creatively was fully achieved. The effectiveness of some methods developed by the students resulted in M.S. thesis and international conference publications. Moreover, inspired by the topic as learned in the fashion proposed here, six former students of this class at Università degli Studi Roma TRE, are now Ph.D. students.

V. CONCLUSIONS

In this paper the experience gained in using an online contest in education for improving both knowledge and human interaction has been presented. The goal was achieved through a competitive-collaborative learning scheme in an information technology security class. It results in an improved understanding of data hiding methodologies problems, autonomously collection of knowledge about the most advanced solutions in the literature, and developing of own solution by understanding their effectiveness and faults. Students feedback and exam performances demonstrate that the use of technology in education is effective, in particular when combined with creative team work. This allows students to collaborate, thus learning how to work together and how to achieve goals by exploiting the skills of all team members. In particular, the game approach allows the groups to increase positive competition and to get involved in the design of high-performance algorithms.

We have also created a group in Facebook (Catch The Mark) with the aim of promoting discussion between students of different universities, of publishing competition rules and schedule details, and of gathering student feedback [13]. The effectiveness of using the social network will be evaluated this year. A web site is also available with all the necessary information about the current year's CTM [14].

REFERENCES

[1] A.W. Chickering and Z.F. Gamson, "Applying the Seven Principles for Good Practice in Undergraduate Education. New Directions for Teaching and Learning", *San Francisco: JosseyBass*, vol. 47, 1991.

[2] S.B. Fiechtner and E.A. Davis, "Collaborative Learning: A Sourcebook for Higher Education", chapter *"Why Some Groups Fail: A Survey of Students Experiences with Learning Groups"*, ed. A. Goodsell and M. Maher and V. Tinto and Associates, pub. University Park: National Center on Post-secondary Teaching, Learning, and Assessment, Pennsylvania State University, 1992.

[3] R.F. Slavin, "Cooperative Learning", *Review of Educational Research*, vol. 50, no. 2, pp. 315-342, 1980

[4] J. Cooper, "Cooperative Learning and College Teaching: Tips from the Trenches", *The Best of the Teaching Professor*, vo. 4, pp. 45-50, 1990.

[5] J. Cooper and Associates, "Cooperative Learning and College Instruction", Long Beach: Institute for Teaching and Learning, California State University, 1990.

[6] UTSA state engineering competition: http://www.utsa.edu/today/2010/03/teamscontest.html, last viewed 07/2010.

[7] IT-Olympics: http://www.it-adventures.org/itolympics.html, last viewed 07/2010.

[8] European COllaborative LEarning network, Comenius 3 action, http://www.ecolenet.nl/index.htm, last viewed 07/2010.

[9] M. Prensky, "Digital game-based learning", New York: McGraw-Hill, 2001.

[10] J. P. Gee, "What video games have to teach us about learning and literacy", New York: Palgrave Macmillan, 2003.

[11] A. Mitchell and C. Savill-Smith, "The use of computer and video games for learning: A review of the literature", Learning and Skills Development Agency, EU-DG: IST-2000-25270, 2004.

[12] W.L. Johnson, H.H. Vilhjálmsson, and S. Marsella, "Artificial intelligence in education: Supporting Learning through Intelligent and Socially Informed Technology", chapter *Serious games for language learning: how much game, how much AI?*, pp. 306-313, ed. Chee-Kit Looi et al., pub. IOS Press, 2005.

[13] http://www.facebook.com/pages/Catch-the-Mark/107903299247580

[14] http://www.comlab.uniroma3.it/ctm_rules_10.html