

# JolasMATIKA: An Experience for Teaching and Learning Computing Topics From University to Primary Education

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**Abstract—Contribution:** A learning-by-teaching methodology through games can be used to promote informatics (computer science) in primary and secondary education. Applying the proposed activities can change students' perception of informatics from seeing it as merely using computers to seeing its relationship with mathematics. The experience can also help students acquire competences in teaching.

**Background:** Although students, specifically in primary and secondary education, are increasingly competent in terms of technology use, it has been found that in many cases informatics, as a science, has been relegated to a secondary status; it is usually considered only as a tool or additional resource, and not as an object of study.

**Intended Outcomes:** To refine the application of the learning-to-teach-to-learn (L2T2L) methodology, a learning-by-teaching methodology that has students learn and then, in turn, teach that learning to younger students, in cascade from university to secondary to primary students. To analyze its effects on students' attitudes toward informatics.

**Application Design:** The model incorporates a learning-by-teaching approach in a multistage sequence across different kinds of learners and teachers, using fun, game-like materials.

**Findings:** The use of the action research methodology allowed adjustment of the educational methodology, providing more reliable data and enough experience to suggest how to extend the project to a broader audience. Although the results obtained were less significant than expected, the experience did give students a more realistic view of informatics.

**Index Terms—**Action research, computing skills, cross-disciplinary skills, games, gender, informatics, learning by teaching.

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## I. INTRODUCTION

HUMAN learning and teaching increasingly needs to be open and explorative, engaging students and teachers in collaborative learning and teaching activities. This is called constructivist learning, and is not a new idea (see [1], [2]). Project-based learning, problem-based learning, and learning by teaching are three different constructivist approaches to human learning and teaching. As Ploetzner *et al.* [3] argued, in a learning-by-explaining scenario, learning takes place, first, during the construction of self-explanations and, again, when that learning is explained to others in an interactive group situation. In other words, explaining to others creates opportunities for learning [4]. These approaches attempt to capture the constructivist notion that “The educative effect is greater when students do something than when something is done to them” [5], together with the reflexion, “Teaching is mostly listening and learning is mostly telling” [6]. All the constructivist approaches, in their particular ways, aim to develop open, forward-looking, “knowledge and understanding are best acquired by building them together” approaches in learners, together with the strong critical thinking, imagination, and teamwork skills that are also needed. Direct teaching methods aim to deliver teaching material to students—the learners who are expected to receive, absorb, and understand the material. Constructivist approaches depend upon incrementally building what is learned and taught.

Today, it is quite usual to find computers in the school classrooms. Although students, particularly in primary and secondary education, are increasingly competent in terms of technology use, it has been found that in many cases informatics, as a science in its own right, has been relegated to a secondary status and is usually considered only as a tool or additional resource, not as an object of study. In this article, the term “informatics” is synonymous with “computer science,” as in [7].

Another issue is that not all schools have an adequate Internet connection for several entire classrooms to be able to have simultaneous access. This makes it necessary to incorporate activities that work on computer concepts without necessarily using computers. Unplugged activities tend to be less costly and resource-intensive than those that requires computer platforms, and thus can reach larger audiences [8]. It also gives the possibility to address learning through games.

The JolasMATIKA project addresses these issues by fostering the visibility of informatics in primary education (6–11 years) and secondary education (12–16 years) with the focus on its scientific characteristics and not in its use as a tool. JolasMATIKA is a compound of the Basque word *jolas* (play), and the end of the Basque word *informatika* (informatics). In English, the name would be something similar to PlayMATICS.

JolasMATIKA proposes three main innovations.

- 1) Students at every education level should understand informatics as a science, and not just as a tool.
- 2) A generic model should be put in place that organizes constructivist learning and teaching to transmit knowledge and learning activities between students of different education levels: first, from university to secondary education, and next, from secondary education to primary education.
- 3) Students in an informatics engineering bachelor's degree program should deepen their knowledge and understand the cross competences of the topic they study.

This article is structured as follows. Section II presents several initiatives that are being carried out at international level with the aim of integrating informatics into the curricula, and the reasons for following that trend. Section III introduces the methodology used to transmit knowledge and pedagogic strategies between different education levels. In Section IV, the selected topics and activities are presented. Sections V and VI describe, respectively, how the project was introduced in schools and the characteristics of the data collected during the process. The results obtained are summarized in Section VII. Finally, the conclusions and future research directions are outlined in Section VIII.

## II. INFORMATICS IN PRIMARY AND SECONDARY EDUCATION

The rapid development of information and communication technologies has obliged educational systems to adapt to current contexts and requirements [9]. This has generated a global movement to introduce informatics, as a science, in the pre-university education curriculum [10], [11]. Although the objective is the same in each country, the process and the state reached vary by country [9].

In some countries, informatics is already part of the curriculum at the national level. In Europe, Estonia was one of the first countries to include computer science and programming in primary education [12]. In the 2014/15 academic year, the U.K. made computer science a compulsory subject in schools after primary education [13]. In Finland, computer science was included linked to mathematics in primary education in the 2016/17 academic year [14]. There are also initiatives in the U.S. where standards have been published to integrate computer science from early childhood to high school [15]–[17].

Elsewhere, the topic has been addressed at the regional level [18]; as a consequence, the situation is different in each region. In Spain [19], in the Basque Country, where the authors

are located, the study of informatics, as a science, at the undergraduate level is only offered in extracurricular activities and optional courses. Nevertheless, the emphasis on the importance of computational thinking is growing.

The term computational thinking was used for the first time by the mathematician, computer scientist, and educator Papert [2] in 1980. Later, in 2006, Wing [20] defined the term as: “formulation of the thought process that a computer (human or machine) has to carry out in order to reach one or more resolutions of a given problem.” During this process, logical reasoning, algorithms, decomposition, abstraction, generalization, and evaluation will all be used. All these steps have use beyond the field of informatics, being needed in many other areas of life.

One of the goals of compulsory education is to ensure that all people have the necessary skills to face not only their own formative actions but their own life in general. In education, the foundations of most sciences are established. These bases will be fundamental for the future of the students, both in life and when making their own decisions.

The authors, therefore, believe that not treating informatics as a science in itself in the educational curriculum from its earliest levels has a direct influence on the fact that students do not undertake higher education in computer science, or if they do, they begin without adequate knowledge of the discipline.

In addition, the understanding of informatics as mere technology does not improve the erroneous image of the field held by society at large [21], [22].

The ignorance of what informatics actually is, combined with its widespread stereotypes, has a negative influence, particularly on the female population [23]. This is a general problem for science, technology, engineering, and mathematics careers [24].

During recent years, the number of women enrolled in the University of the Basque Country (UPV/EHU) has decreased; certain initiatives have been launched to address this problem. More women are being included in the outreach activities of the computer science program at UPV/EHU. For example, women participate in initiatives, such as the teaching of some lectures in secondary schools, participate in the science week carried out yearly in the Basque Country, develop practical sessions explaining what computing is, organize summer schools, etc. In addition to encouraging the presence of women in these forums, they also provide experiences that are of interest to this particular section of the young population. However, these initiatives have not had the expected effect. Researchers suspect that the fundamental reason behind this is that students have already internalized a series of stereotypes of each profession by the time they reach secondary education. This underlines the need to change the image held about informatics from an early age.

Taking all the above into account, the authors started a project to spread the treatment of informatics, as a science, from university education to secondary and then to primary education, letting the knowledge flow from higher to lower education, from students who know more about the subject downward. Students take the teacher role and teach to their

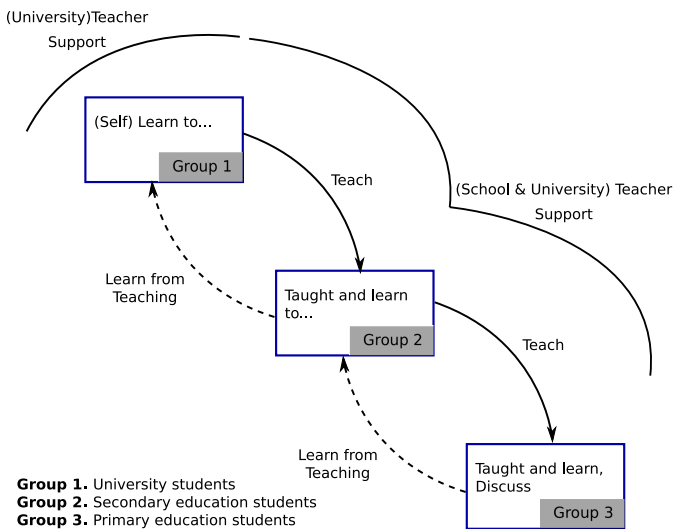


Fig. 1. Learn-to-teach-to-learn model (L2T2L).

younger peers in a cascade model, leaving to the teachers the role of supporting them.

### III. METHODOLOGY

As pointed in Section I, one of the stages of JolasMATIKA introduces innovation in the design of pedagogical strategies to transmit knowledge about learning activities between students of different levels of education. The work presented in this article was intended to evaluate the *learning-by-teaching* methodology that has already been used in university settings [25]–[27]. JolasMATIKA has students transmitting informatics knowledge they have learned to students in a previous educational stage—so from university education to secondary, then from secondary to primary. Taking the dual roles of learners and teachers helps students further their knowledge of informatics. The action research methodology [28] was used in the project. After an analysis of the evolution and outcomes of the first year’s pilot project, some modifications (see Sections V and VII-A) were made to fine-tune the process for the second year.

The model followed in JolasMATIKA incorporates a learning-by-teaching approach in a multistage sequence across different kinds of learners and teachers. This generic model, called the learning-to-teach-to-learn (L2T2L) model, Fig. 1, has deep roots stretching back to Seneca and his observation “Homines dum docent discunt” [while they teach, men (people) learn] and is designed to include typical learning and teaching activities, such as preparation, presentation, and assessment [26]. The L2T2L model is built to capture the kinds of active thought and reflection, analysis, identification, and selection of main ideas, and the forming of concepts into one’s own thoughts and words, central to constructivist learning and teaching [29].

In the first block, group 1 students (university students) work together to teach themselves the domain topic, and plan and organize what to teach on this topic to the students in group 2 (secondary education students), and how to present and teach it. Group 2 students, as part of their learning, plan

and organize the topic they are learning to teach to the group 3 students (primary education students). Finally, the group 3 students, the youngest ones, as part of their learning, discuss with their supervisors what they have learned. Each group is supported and supervised by professional teachers, who can advise the students involved, and make sure that sensible and reasonable learning and teaching takes place. The differences between the groups are, in this case, age and educational level (university and secondary or primary education).

### IV. TOPICS AND ACTIVITIES

In JolasMATIKA, the topics were selected so as to familiarize and engage the youngest students with informatics. So the topics needed to include the basic informatics concepts, they had to be adapted to the youngest students’ thinking and learning characteristics, and they needed to be “fun” and encouraging.

Being aimed at a young population, it was considered essential to enhance any potential playful features there might be when developing the different activities. To this end, the university lecturers participating in the project identified the topics and generated the material to be used in it using computer resources aligned with this purpose (see CS Unplugged [30], or Bebras [31] among others).

The learning and teaching topics initially selected for JolasMATIKA activities were as follows.

- 1) Introduction to computational thinking.
- 2) Information representation in computers. Binary system and image representation.
- 3) The basis of programming. Algorithms, instruction sequences loops, conditional structures, etc.

Each of these topics was considered important because of the following.

- 1) They can generate interest about informatics with topics and assignments not apparently linked to computing. Various exercises of the Bebras tool [31] were selected according to the level of the students.
- 2) Information in computers is coded in binary. So it was considered crucial to have a grounding in the binary system and data representation in computers to better understand how they work. Moreover, working with binary code can be appealing yet challenging for students. Also, images are very important in human lives and knowing how they are represented in computers can also be intriguing for students. To introduce these concepts, first, a magic game proposed in MATHManiaCS [32] was proposed. Next, to work on the basics of the binary code, the cards with points proposed in CS Unplugged [30] were used.
- 3) Computers execute programs, and programming will be compulsory in any field of informatics. In that sense, any basic knowledge transferred about informatics needs to introduce some programming skills to the students. The suggestion in JolasMATIKA is to start on working on these concepts by introducing simple problems that can be solved graphically or physically, such as the construction of plastic or paper cup towers proposed by

Thinkersmith and now available at [33],<sup>1</sup> and going onto more complex problems until reaching the search and sort algorithms. To illustrate and help students think about how the search and sort algorithms work, cards with numbers from 1 to 100, randomly distributed to the students, were used. Before thinking about the programs, cards physically illustrated how the numbers can be sorted or how a specific value can be found. Next, the exercises proposed in Code.org [33] were employed; instead of using computers, physical pieces that join together like a puzzle were used. At the end of the process, a programming exercise using Scratch [34] or Blockly [35] was proposed, starting from a provided base program.

Although the main content of the material used in different levels is the same, the teaching units were adapted to each level.

## V. IMPLEMENTATION

The JolasMATIKA project was launched in the 2016/17 academic year and repeated with some modifications in the 2017/18 academic year. It was carried out in the Gipuzkoa region in Spain, with the participation of teachers and students from the Faculty of Informatics at UPV/EHU, Donostia-San Sebastian, Spain, and two schools located in Tolosa, Spain, interested in teaching informatics as a science from early stages: 1) ORIXE public secondary school and 2) SAMANIEGO public primary school.

For the first year of the project, ten 1-h sessions were planned. Two of them (the first and the last) were used to obtain data on the attitude toward computers of all students in the sixth grade of primary school [11 and 12 years—67 students, 27 (40.3%) boys and 40 (59.7%) girls, distributed into three groups] and the ICT students of the fourth grade of secondary school [15 and 16 years—15 students, ten (66.6%) girls and five (33.3%) boys]. For the rest of the sessions, two male students from the computer engineering degree course (group 1) analyzed the aforementioned teaching material and agreed on the activities with the teaching staff involved in the project. The first year, group 1 students had ten sessions with secondary school students (group 2), who had ten more extra sessions to prepare their teaching and, finally, taught ten sessions to the primary school students (group 3). The number of teachers of secondary and primary school were conditioned by the involved number of groups.

By using the action research methodology, some modifications were made to fine-tune the process for the second year through collaborative work between the university lecturers, the primary school teachers, and the secondary school teachers. During the action, information about the process was gathered and analyzed, and the relevant decisions were taken jointly in order to improve the project. In this case, for the second year, the number of sessions group 1 students (three new students, two male and one female) used to teach group 2 students [13 students, nine (69.2%) boys and four (30.8%) girls] were reduced to five, and the number of preparation

TABLE I  
LIST OF THE CLOSED STATEMENTS INCLUDED IN THE SURVEY

Item #	Statement
1	Using the Internet is central in informatics.
2	Using text editors (Google Docs, Word...) is central in informatics.
3	Installing software/programs is central in informatics.
4	Programming is central in informatics.
5	Being able to solve different problems is central in informatics.
6	I think I am capable of studying informatics.
7	Informatics is an area related to math.
8	I am good at science.
9	The computer scientist should be good at cooperation.
10	The computer scientist is a nerd.
11	When I grow up I want to work in informatics.
12	Boys are better than girls when studying informatics.
13	The computer scientist should have a mathematical way of thinking.
14	Work in informatics requires long hours.
15	When I grow up I want to study informatics.
16	Working in informatics is fun.
17	The computer science worker earns a lot of money.
18	I am good at math.
19	Work in informatics can be done without a computer.
20	Informatics is a boring subject.
21	Informatics is used almost in all professions.
22	People who work in informatics should use their creativity.
23	In general, I like informatics.

sessions for group 2 students and the number of sessions for group 3 students [65 students, 34 (52.3%) girls and 31 (47.7%) boys distributed into three groups] was maintained. The topics included in this new experience were also adjusted: data representation, programming issues, computational thinking and algorithms, development of a project, and finally, presentation of the project.

## VI. DATA COLLECTION

For data collection, the first and the last sessions in each academic year were used to obtain data on the attitude of students toward informatics.

The main objective of JolasMATIKA is to start to change the perspective, attitudes, and intentions of this group of students with regard to informatics. In their research, Taub *et al.* [36] proposed the following research question: “What is the effect of CS Unplugged on the perspective, attitudes and intentions of seventh grade students with respect to computer science?” As JolasMATIKA has an almost direct relationship with the question proposed by Taub *et al.* [36], it was considered appropriate to rely on a survey very similar to that proposed in [36]. The authors took that as a base and included, adapted, and removed some statements. The resulting final survey consists of 23 closed-ended statements (Table I) with five values on a Likert scale of 1–5, where 1 represents “total disagreement” and 5 represents “total agreement.” In addition to these closed-ended statements, the following open-ended questions were also asked: Is informatics interesting? Why? How do you think knowledge on informatics can help you?

In the final session, the same survey was carried out again in order to check if this brief introduction to computer science

<sup>1</sup>My Robotic Friend: <https://curriculum.code.org/csf-1718/courseb/6/>.

TABLE II  
COMPARISON BETWEEN PRE-TEST AND POST-TEST RESULTS WITH  
PRIMARY AND SECONDARY EDUCATION STUDENTS IN THE  
FIRST YEAR OF THE JOLASMATIKA EXPERIENCE

Item #	Primary education				Secondary education			
	Avg pre-t	Avg post-t	p-value	Cohen's D	Avg pre-t	Avg post-t	p-value	Cohen's D
1	3.35	2.89	0.030 *	0.39	3.07	2.79	0.297	0.10
2	3.31	2.63	0.002 **	0.53	2.79	3.07	0.464	0.15
3	3.08	2.95	0.277	0.10	3.14	3.07	0.791	0.09
4	3.56	3.78	0.479	0.18	3	4.07	0.026 *	0.85
5	3.63	3.71	0.366	0.07	2.64	3.43	0.072	0.61
6	3.66	3.66	0.793	0	3.14	2.79	0.163	0.34
7	3.68	4.35	0.001 **	0.54	3.23	3.77	0.176	0.22
8	3.10	3.34	0.102	0.22	3	2.86	0.720	0.16
9	3.82	3.52	0.155	0.26	3.07	3	1	0.07
10	2.56	2.46	0.639	0.07	2.60	2.51	0.102	0.40
11	2.55	2.54	0.614	0.01	2.14	1.71	0.153	0.54
12	1.58	1.79	0.330	0.21	1.25	1.33	0.785	0.17
13	3.38	3.79	0.077	0.37	2.50	3.29	0.072	0.49
14	3.49	3.25	0.299	0.25	2.64	2.86	0.597	0.31
15	2.90	2.84	0.307	0.04	2.29	1.93	0.248	0.47
16	3.89	3.68	0.090	0.19	2.93	2.29	0.112	0.58
17	3.30	3.50	0.317	0.22	2.71	2.71	1	0
18	3.31	3.51	0.210	0.17	3.38	3.53	0.336	0.25
19	2.62	3.60	0.000 **	0.72	2.67	3.53	0.048 *	0.61
20	1.95	1.85	0.534	0.13	1.86	2.64	0.027 *	0.84
21	3.49	3.44	0.405	0.05	3.31	3.85	0.096	0.28
22	3.53	3.61	0.923	0.09	3.43	3.57	0.564	0.12
23	4.13	4.00	0.265	0.12	3.50	3.14	0.317	0.37

and programming helped to improve the attitude of the students toward informatics. In every use of the questionnaire, the reliability coefficient of the questionnaire was obtained using Cronbach's alpha value. In all cases, the value obtained was around 0.70, which is an acceptable value in this type of questionnaire [37], [38].

In addition, at the end of every session, group discussions were held between the different actors involved: students of groups 1–3, the people in charge of the tutorials of the primary education groups, and the teachers of information and communication technologies from the secondary education group.

All participants' parents or tutors signed an informed consent document showing their willingness to collaborate in the research project.

## VII. RESULTS AND DISCUSSION

This section presents and discusses the results of the two-year experience.

### A. First-Year Results (2016–2017 School Year)

In Table II, the comparison between pre-test and post-test results for primary and secondary education students during the first year of JolasMATIKA are shown.

The test was completed by students at the beginning of the experience (the pre-test) and at the end of the experience (post-test). The nonparametric Wilcoxon test for related samples was used to check for significant differences between pre-test and post-test. In Tables II–IV, \* means that the difference is significant at 0.05 and \*\* means that it is significant at 0.01. Also included is the effect size calculated by Cohen [39].

As seen in Table II, there are significant differences for primary education students for items 1, 2, 7, and 19. That is,

TABLE III  
COMPARISON BETWEEN PRE-TEST AND POST-TEST RESULTS WITH  
PRIMARY EDUCATION AND SECONDARY EDUCATION STUDENTS IN THE  
SECOND YEAR OF THE JOLASMATIKA EXPERIENCE

Item #	Primary education				Secondary education			
	Avg pre-t	Avg post-t	p-value	Cohen's D	Avg pre-t	Avg post-t	p-value	Cohen's D
1	3.79	3.48	0.099	0.28	3.31	3.62	0.499	0.30
2	3.34	3.27	0.613	0.06	3.15	3.31	0.608	0.23
3	3.26	2.84	0.055	0.35	2.92	3.15	0.530	0.19
4	3.65	3.82	0.273	0.16	3.45	4.08	0.070	0.56
5	3.48	3.35	0.301	0.12	3	3.31	0.469	0.34
6	3.89	3.61	0.098	0.27	3.23	3.77	0.142	0.40
7	3.43	3.82	0.071	0.32	3	3.31	0.476	0.34
8	3.13	3.21	0.431	0.07	2.77	3.08	0.588	0.22
9	3.85	3.93	0.386	0.08	3.08	3.69	0.191	0.49
10	2.19	1.93	0.237	0.20	1.46	1.77	0.339	0.60
11	2.35	2.48	0.637	0.11	2.31	2.92	0.168	0.49
12	1.26	1.33	0.643	0.09	1.46	1.46	1	0
13	3.15	3.35	0.227	0.16	2.08	2.77	0.203	0.66
14	3.39	3.33	0.676	0.05	3.08	3.38	0.407	0.31
15	2.76	2.63	0.132	0.10	2.23	2.85	0.131	0.42
16	3.71	3.26	0.019 *	0.40	3.31	2.85	0.107	0.41
17	3.17	2.98	0.320	0.19	2.77	3.15	0.160	0.33
18	3.51	3.45	0.670	0.06	3.08	3.38	0.357	0.19
19	2.57	2.77	0.140	0.14	2.23	2.85	0.130	0.44
20	1.89	2.06	0.398	0.15	2.62	2	0.059	0.49
21	3.77	3.47	0.253	0.29	3.58	3.69	0.726	0.09
22	3.70	3.58	0.904	0.12	3.54	3.69	0.623	0.14
23	4.24	3.48	0.000 **	0.81	3.85	4	0.480	0.12

TABLE IV  
COMPARISON BETWEEN GIRLS AND BOYS OF PRIMARY EDUCATION IN  
THE PRE-TEST AND IN THE POST-TEST

2016-2017								
Item #	Avg in pre-test			Cohen's D	Avg in post-test			Cohen's D
	Girls	Boys	p-value		Girls	Boys	p-value	
6	3.47	3.96	0.147	0.44	3.56	3.77	0.459	0.16
11	2.26	3.05	0.680	0.56	2.03	3.43	0.000**	1.17
12	1.44	1.83	0.210	0.39	1.76	1.70	0.895	0.05
15	2.64	3.33	0.670	0.49	2.64	3.26	0.101	0.44
23	4.03	4.29	0.288	0.25	3.95	4.09	0.541	0.12
2017-2018								
Item #	Avg in pre-test			Cohen's D	Avg in post-test			Cohen's D
	Girls	Boys	p-value		Girls	Boys	p-value	
6	3.79	4.00	0.681	0.23	3.53	3.70	0.522	0.14
11	2.03	2.75	0.032*	0.62	1.94	3.07	0.001**	0.94
12	1.06	1.50	0.023*	0.63	1.26	1.40	0.648	0.30
15	2.38	3.21	0.028*	0.64	1.87	3.43	0.000**	1.29
23	3.97	4.57	0.010*	0.71	2.87	4.13	0.000**	0.96

students felt that using the Internet and text editors is not real informatics. Informatics has a relationship with mathematics and it is possible to use informatics without computers. This is very much in alignment with the objectives of the project.

Data for secondary education students, Table II, are not as significant as for primary education students. Fewer students were involved in the activity, which might have had some influence on the resulting data. There were significant differences for items 4, 19, and 20. That is, after the experience they felt that programming was more central in informatics, that informatics can be used without computers, but that it is more boring. This could be understood as, after the experience, students treating informatics as something more serious than just games.

At the end of each year's experience, sessions eliciting feedback were held with each group: the Faculty of Informatics students, secondary education students, primary education students, secondary education teachers, and primary education

teachers. Discussion scripts were prepared, differing slightly between groups. In general, participants were comfortable with the JolasMATIKA experience. From the teachers' perspective, the time devoted to JolasMATIKA was considered as valid in terms of covering the topics of their subject, in secondary education, and for acquiring curriculum competences in primary education. Students liked the topics, and their ideas of informatics had evolved.

Analysis of the first year's results showed the need for some improvements, introduced in the second year.

- 1) *Coordination*: The authors and students from the Faculty of Informatics need more frequent meetings with primary and secondary education teachers to help them better understand procedures and contents, and to respond to questions.
- 2) *Number of Sessions on Secondary Education*: The secondary education students receive lectures from the students of the Faculty of Informatics, give lectures to primary education students, and need to prepare the lectures to teach to primary education students—resulting in very many JolasMATIKA sessions for them. Therefore, in the second year, faculty students only gave five sessions to secondary students, instead of ten.
- 3) *The Preparation of the Student-Teachers*: Some university and secondary education students needed more pedagogical coaching.
- 4) *Students' Level*: Although some students understood and were able to manage the concepts very quickly, even becoming bored in the latter stages, others clearly had difficulties. The second year's material was therefore prepared to allow for different levels of ability. Advanced students could work on applying the concepts, while other students could work on understanding them.

### B. Second Year Results (2017–2018 School Year)

The second year's results were analyzed as for the first year. Table III shows the comparison between pre-test and post-test results for primary education and secondary education students.

In general, the results are very similar to those obtained during the first year's experience. However, in the second offering, there were fewer significant differences on the tested issues. These only appear in items 16 and 23, that is, the students found informatics less fun and liked it less after the JolasMATIKA experience. They seemed to understand that informatics is not just games but a serious matter as any other science.

There are some differences between the results of the two years. The biggest one appears in the values associated to item 1 in primary education, about to the relationship between the Internet and informatics. According to item 12, the second year's students found less difference between men and women in informatics and considered computer scientists to be less "nerdy."

Although, in general, students' attitudes improved in most of the dimensions considered, these differences were not statistically significant. The results obtained are similar to those

obtained in the first year of the experience. The most obvious difference was perhaps in item 23 (in general, I like informatics) given that the first year of the experience the average fell and the second year, in secondary education, it rose.

### C. Gender Viewpoint

One objective of the project was to analyze differences between females and males, and see whether the project could reduce these. Questionnaire items (6, 11, 12, 15, and 23) that can indicate willingness to study or work in informatics in the future were analyzed.

To monitor the differences between girls and boys, Mann-Whitney's nonparametric U-test was used for unrelated samples. Table IV shows the results for those items (listed above) that could have had a different gender response.

Both girls and boys considered that they were capable of studying informatics (item 6), with no significant differences between them, both in the pre-test and in the post-test for each of the two years.

However, when asked whether they intend to work in informatics when they grow up (item 11), the differences between girls and boys are striking. Boys showed a greater predisposition to work in informatics than girls, with this tendency being accentuated after the experience in both years. Something similar happened when they were asked (item 15) if they intended to study informatics. Although the first year's responses were not clear, in the second year, the difference between their intentions to study informatics increased. This predisposition to study or to work in informatics does not correlate to the possible different capacity that they may have. When (item 12) they were asked if boys are better at informatics than girls, the averages were very low. Moreover, although some small differences were found in the pre-test in favor of the boys, these disappeared in the post-test.

Finally, when asked if they like informatics, the averages are around 4, so the score can be considered to be high in almost all cases. However, in all cases, the post-test score was significantly lower than the pre-test score. In this case, although in the first year, there were no differences between boys and girls, in the second year, boys were keener on computers and this difference accentuated after the experience. In both cases, the differences were statistically significant.

### D. Discussion

The pre- and post-test carried out in the project during the first and last sessions of each academic year, using the questionnaire shown in Table I, allowed the authors to analyze how students' opinion of informatics changed. The questionnaire addresses five main aspects of their relationship with informatics with the following sets of statements.

- 1) *Set1*: Statements 1–3, 7, 19, and 21 refer to seeing informatics as a science or as just technology in use.
- 2) *Set2*: Statements 4 and 5 refer to what extent programming and computational thinking are important to informatics.
- 3) *Set3*: Statements 6, 8, 12, and 18 are more related to self-esteem than to their impression about informatics.

- 4) *Set4*: Statements 9, 10, 13, 14, 17, and 22 refer to how the students perceive the computer scientists or people working in informatics.
- 5) *Set5*: Statements 11, 15, 16, 20, and 23 analyze the extent to which the students like informatics.

Tables II and III show the analysis of results for primary students, showing the varying impact of the activities in the different areas. Secondary education data were discarded because of the few responses collected. For some of the aspects, self-esteem (*Set3*) and perception of the computer scientists (*Set4*), the differences between the tests do not show a specific trend. Thus, how the project affects them cannot be expressed.

Observing the items in *Set1*, it can be said that the experience was successful since students' perception of the relationship of informatics with maths increased, and perceptions, such as informatics being merely use of the Internet or computers decreased. Thus, students' understanding of possibilities of working in informatics without computers has increased. This occurred in the first year with significant differences.

With regard to *Set2*, the students do not seem to understand to what extent programming is related to solving problems, since their perception of the relationship of programming to informatics increases while the relationship with solving problems decreases.

Finally, focusing on whether students like informatics, *Set5*, students seem to have learned that informatics is not just a game but a serious topic and, consequently, their perception of informatics as being fun and, thus, liking it decreases. However, the willingness to work in informatics is maintained or increased. For the future, researchers are considering some approaches related to game theory in computer engineering to make *JolasMATIKA* more fun to the students.

Interpretations of the results are limited by this article only having a small number of participants. As mentioned, in all analyses where it was possible, the effect size was calculated (see Tables II–IV). Another limitation is that the study was carried out in only one location, for just two consecutive years. Therefore, more studies are needed to test its validity with other schools and for a longer period.

## VIII. CONCLUSION

This article presented a two-year experience of *JolasMATIKA*, a project proposed to explain informatics as a science by university students to secondary students, and by secondary students to primary students.

*JolasMATIKA* incorporates a generic learning-by-teaching model, called L2T2L, that allows knowledge of informatics to be transmitted between students at different educational levels in cascade (Fig. 1). In each implementation of the model, students carried out both the learning and the teaching at each stage. The learning and the teaching were not required to be of the highest level, but had to be good enough. The authors needed to verify this, and how it was seen by professional teachers. By having students do the learning and the teaching, and having teachers help the authors make sure this goes well,

the authors were able to keep the project compact and simple to organize and manage. If the authors had involved the teachers directly in the learning and teaching, other independent teachers would have been needed to assess the learning and teaching.

Although the results achieved are quite positive, they are currently under thorough analysis in order to adjust and update the experience for each forthcoming academic year, in accordance with the action research methodology. For example, a new topic is to be introduced during the next course: computer architecture. Basic blocks will be presented, along with an introduction to how the system works to execute programs, all in a similar way to the previous topics.

With the aim of involving more students, the authors plan to spread this project to more primary and secondary schools in other locations. The biggest hurdle to overcome in extending the project to more places is the limit imposed by the number of students involved at the university level. Therefore, several learning kits are being prepared, each one with its own didactic unit.

In the future, the authors would also like to engage teachers from other degree courses to test the learning-by-teaching L2T2L model. The authors feel the model is generic enough to be applied not only in technical subjects but also in more theoretical ones.

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