Applying Mindstorm in Teaching and Learning Process and Software Project Management

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***Abstract*—Some problems related to software process and project management improvement programs are detected during their implementation. Companies from the software projects segment have difficulty dealing with software Project management and quality models (CMMI, MPS-BR and PM-BOK) since the ways to implement the key areas of the process and the good practices inherent to Project management are interpreted with difficulty. This can be attested by the analysis of CMMI and CHAOS reports. In order to minimize the difficulties detected by the reports, the aim of this paper is to apply Mindstorms to the teaching and learning of software process and project management (key concepts used during process improvement and implementation). To validate the efficacy of the technique introduced in this paper, 8 experiments were carried out including university, high school courses and companies from the software production sector. Experimental results attest that the process of knowledge transfer in process and management using Mindstorms led to greater motivation, satisfaction and concepts consolidation.**

Keywords— Software Project management; Software Process; Teaching and Learning; Mindstorms.

I. INTRODUCTION

Some problems related to software process and project management improvement programs are detected during implementation.

This fact can be attested through the analysis of CMMI and CHAOS reports.

In regards to process improvement, South America has 400 CMMI certified companies whereas India has 760. One of the greatest company's problems appointed by the CMMI report is to develop the necessary knowledge inherent to the creation and institutionalization of software processes.

In relation to management, 60% of 900 projects were either not concluded or had their time, cost or scope reduced. According to the CHAOS report, companies do not have efficient techniques to develop a project.

Universities are responsible for changing this scenario. To do so, they must create motivating processes to promote satisfaction and knowledge consolidation during their transference.

Within this context, the objective of this paper is to apply Mindstorms to the teaching and learning of software process and project management.

Currently, most research using Mindstorms as their teaching and learning object are found in the area of Programming (see Section 2). This paper's innovation is based on the use of Mindstorms as a resource for teaching process and process management.

Taking into consideration this context, this article tries to answer two questions:

1. Is it possible to apply Mindstorms as the object of teaching and learning process and project management?
2. Does the application of Mindstorms provide motivation during knowledge transfer in process and project management?

To validate the referred application, the authors of this paper carried out, from 2010 to 2014, 8 experiments, divided into two phases:

A. From 2010 to 2012, the authors worked traditionally, i.e., without using Mindstorms as the object of process and software management teaching and learning. In this phase, 2 experiments were realized with 86 students from the Computer Engineering and Systems Analysis courses offered by Universidade Tecnológica Federal do Paraná (UTFPR), Campus of Cornélio Procópio.

B. In the year 2013 and 2014, the authors carried out 6 experiments using Mindstorms as the object of software process and project management teaching and learning, with the duration of 345 minutes each. Four of them with Universidade Tecnológica Federal do Paraná (UTFPR) – Campus de Cornélio Procópio undergraduate courses; one with students (16) from the Systems Analysis Course; one with students (20) from the Computer Engineering Course and one with students (12) from the Graduate Program in Computing. One experiment was realized with 4 high school students and, finally, one in a company from the software production sector (4 collaborators). Total of students: 68.

During the experiment carried out in a traditional way - Phase A - 64.86% of the students absorbed the concepts related to software process and project management naturally. This percentage was captured by a formative evaluation[1] applied to students in subjects that deal with software process and project management concepts.

Experiments with Mindstorms - Phase B - It was possible to verify that 88.2% of the students absorbed the concepts related to software process and project management naturally, mainly under the perspective of activities planning and implementation. This percentile was captured by a formative evaluation and software project implementation, using a historical basis.

To verify whether Mindstorms promotes motivation in transferring knowledge about software process and project management, the authors of this paper mapped the level of satisfaction of the participants in the experiment - Phase B. Around 90% of them classified the level as 5 - very high level or 4 –high level (on the Likert scale).

To meet the proposed objectives, this paper was divided into 6 sections. Section 2 presents the works related to the use of Mindstorms in the academic environment. Section 3 proposes the application of Mindstorms to the teaching and learning of software process and project management. Section 4, introduces the methods and procedures used to validate the proposal. Section 5 presents the inferred results with the application of Mindstorms to the teaching and learning of software process and project management. Finally, Section 6 discusses the conclusions delineated by this work.

II. Related Works

The Mindstorms EV 3 is an evolution of the NXT version. The EV3 is a robotics kit focused on technological education and this kit contains a processor, a proprietary software and touch, light and sound sensors. More information about the Mindstorms visit the site: www.lego.com/en-us/mindstorms.

Currently, the use of Mindstorms [1] as a pedagogical tool includes the areas of Automation, Control, Robotics, Physics, Math and Computer Programming.

Brandt and Colton [2] use Minsdstorms to teach Programming, mechanics and control to freshmen students from the Brigham University Mechanics Engineering Department. The objective of the work is to introduce interface and sensing. The authors conclude that Mindstorms is a versatile platform which is greatly accepted by the students. With its use, the authors have improved the learning of Mechanics, Sensors Calibration, Programming Language and the Principles of Physics.

A proposal to systematize the teaching and learning of Robotics with the use of Mindstorms was developed by Universidade Federal de Campina Grande in 2008. In this paper, the authors [3] present a technical bias that permeates the proposal.

Tester [4] used Mindstorms to develop skills connected with innovation and communication management. The work was developed with 70 students from a Northern Arizona University Graduate Course. Results were collected by the author through direct observation of the students' behavior. The author concludes that most students gained considerable knowledge about the area of Communication Management.

Mindstorms has also been used Schumacher, Welch, Raymond [5] to teach Programming to Electrical Engineering and Computer Science freshman students from the Military Academy in the US. The authors conclude that the use of Mindstorms turned the solutions of complex problems by the students more dynamic and with a greater degree of accuracy.

Caci and D'Amico [6] used Mindstorms to develop cognitive skills in children. The authors work with cognitive principles focusing on non-verbal intelligence, visual communication, logics and robots programming. The authors worked with ten 11 -year-old students, divided in 2 groups with 5 students each. The groups worked on the physical construction of a robot and developed, in 12 meetings, a logic project using processes connected to Programming. After the development of the work, the authors conclude the cognitive skills go under significant improvement.

Calvo and Parianaze [7] propose the union of Mindstorms and PBL (Problem Based Learning) for the teaching of Programming in Electronics Engineering and Industrial Engineering Computing subjects. The authors report on experiences carried out in 2008 and 2009. The work concludes, qualitatively, that the students improved significantly their learning in questions related to Computer Programming.

Researchers from Dresden University and Málaga University developed 3 experiments at the graduate level, using Mindstorms [8]. Skills connected to the project and software development were delineated together with the students that used the referred robot. The authors proposed to the students a competition using Mindstorms. During the competition, the students had to develop software in which the robot was able to exit any maze. The authors concluded that the application of the technique improved significantly issues related to the development of structured programs and the understanding and the work with sensors and actuators.

Gandy et al. [9] used Mindstorms in the University of Sunderland Computing Department., UK in 2008 and 2009, to teach Java Programming. The work was developed with graduate students. The authors of the work used Lejos (Java Virtual Machine that works together with Mindstorms). The work was carried out with 49 students and 85% of them stated that the robot collaborated decisively with the learning of the language.

Finally, there are several other works that use Mindstorms as the object of learning [10]. They all apply the referred object to a restricted group of students to teach concepts connected with Computing and Engineering.

[1] The objective of the formative evaluation is to provide subsidies so that the students can understand their own learning process and the functioning of their underlying cognitive capacities during problem solving.

III. Applying Windstorms in the Teaching and Learning of Software Process and Project Management

The application of Mindstorms to the teaching and learning of software process and project management was divided into 3 phases (see Figure 1):

1. The objective of Phase 1 is to compose and introduce the theoretical background that will characterize the teaching and learning environment. In our case, this theoretical background is characterized by questions connected with software process and project management. In this phase, the teacher or tutor is responsible for composing the material and introducing it to the student. The introduction can be done during the lesson (traditional classroom) or use Distance Learning techniques.
2. In Phase 2, the teacher or tutor is responsible for the selection and composition of objects that will characterize the motivating environment for the teaching and learning. In our case, Mindstorms was the selected object. The responsibility of the professor/tutor in this phase is to define the way the student will work with the objects and map the abstract questions related to the theory, make them concrete.
3. The objective of Phase 3 is to assess the whole learning process. This assessment takes place in two steps: 1 - the student is evaluated through tests or practical works; 2- the teaching and learning process is evaluated by the students.

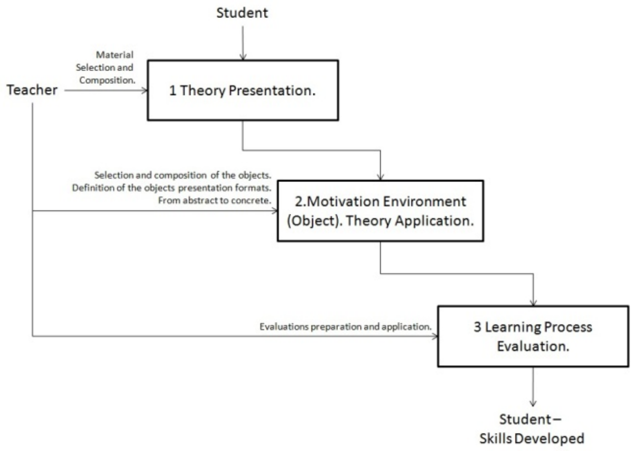

Fig. 1. Model used to compose this work

An analysis of Fig. 1 shows that it is possible to verify that the model can be used for the teaching and learning of any content. In this work, the model was applied using Mindstorms as the object of software process and project management teaching and learning. An example of the model is given in Table I.

Table I was constructed as a development plan for working in a teaching and learning environment. In this table, it is possible to find slides that compose the theory, the object (Mindstorms) and the evaluation criteria. The validation of this plan is the subject of the next section of this work.

TABLE I. Model for the teaching of Process and Project management using Mindstorms

1. Theory Presentation	Process	Slides on software processes: https://dl.dropboxusercontent.com/u/3525445/mindstorms/softwareProcess.ppt	Worked during one traditional class (50 minutes). Available by Ian Sommerville [11]
	Project management	Slides on project management https://dl.dropboxusercontent.com/u/3525445/mindstorms/projectManagement.ppt	Worked during one traditional class (50 minutes). Available by Ian Sommerville [11]
2. Motivation Environment Composition Object Selection Theory Application	Classroom	Division of students into groups of 4 students.	Students developed projects, supervised by teachers, (see Fig. 2) using MIndstorms to concretize abstract concepts, tasks, activities, entry and exit artifacts, tools, skills, plans, project implementation, project control (150 minutes).
	Mindstorms	Presentation of Mindstorms to students. Presentation of the software that manipulates motors and sensors. Traditional class – 45 minutes.	
3. Evaluation	Students	In class evaluation, essay questions (see Table VI).	Evaluation was carried out after the students developed the projects using Mindstorms (see project scope in Fig. 2). Time (25 minutes).
	Teaching and Learning Process	After theory presentation and projects development, students evaluated the teaching and learning process (time: 25 minutes).	

IV. Methods and procedures used to validate the application

In order to answer the questions raised in Section I and evaluate the application of Mindstorms to the teaching and learning of software process and project management, the authors of this proposal developed, from 2010 to 2014, 8 experiments in academic (university) and business (software production sector) environments (See Table II).

Six experiments (realized from 2013 to 2014) were compared to other 2 experiments carries out from 2010 to 2012. The experiments carried out from 2010 to 2012 presented the concepts inherent to software process and project management traditionally (the authors of this paper worked the content on process and project management through lectures), i.e., without Mindstorms.

The experiments in the academic environments were carried out at the Universidade Tecnológica Federal do Paraná Computing Department, Campus of Cornélio Procópio. The Department offers 3 undergraduate courses: Software Engineering, Systems Analysis and Development Technology and Computing Engineering. In addition to these undergraduate courses the Department also offers a Graduate Program in Computing (GPC).

One of the experiments that used Mindstorms was realized with high school students. These students participate in the project Implementation of a Digital Wardrobe by High School Students from Northern Paraná as scholarship holders. The objective of this project was:

1. Recruit future professionals (female) for the Computing Engineering and Software Engineering or Technology;
2. Consolidate contents related to computer programming and software process and project management.

The project was financed by the Brazilian National Council for Scientific and Technological Development- CNPq.

TABLE II. INFORMATION ON THE EXPERIMENTS

Course	Application /Semester	Subjects	Students
Systems Analysis	6th semester (2010,2011,2012)	Software Project management (without Mindstorms)	47
Computing Engineering	7h semester (2010,2011,2012)	Software Project management (without Mindstorms)	39
High School (HS)	6th semester (2014)	Introduction to Project management	4
Software Engineering (SE)	1st semester (2014)	Introduction to Software Engineering	20
Systems Analysis	6th semester (2013)	Software Project management	16
Computing Engineering (CE)	7th semester (2013)	Software Projects Mnagement	12
Graduate Program in Computing (GPC)	1st semester (2013)	Software Engineering	12
Company from the Production Sector (CPS)	IT professionals (2014)	*Consulting for the implementation of a software process*	4*
*Collaborators: Information System (2 collaborators). Systems Analysis (2 collaborators). Each group of 4 students manipulated Mindstorms.			

Through the analysis of Table II it is possible to notice the presence of 6 experiments carried out in academic environments, 1 in a high school and 1 experiment realized in a company's production sector.

The company has a team of 9 people and 4 programmers from the production (programming) cell participated in the experiment. It is important to highlight that the authors of this work have not been formally authorized to disseminate the name of the company. The experiment conducted at this company was part of a software process improvement consulting developed by the authors of this work.

All experiments followed the model adopted by this work (Fig.1 and Table 1). Based on this model, the, as teachers implemented the following actions:

1. Presentation of two traditional lessons on concepts connected with software process and project s management. Duration of each lesson is 50 minutes. Support material to be used during software process [11] and project management [11] lessons can be found in the following links https://dl.dropboxusercontent.com/u/3525445/mindstorms/softwareProcess.ppt. and https://dl.dropboxusercontent.com/u/3525445/mindstorms/projectManagement.ppt.
2. Divide de students into groups of 4.
3. After having grouped the students, introduce Mindstorms to them. During the presentation, teachers work the motors, sensors and actuators. Presentation time was 45 minutes. It is important to emphasize that the teachers used the presentation this link https://www.youtube.com/watch?v=jh9u_B42ILo[2]
4. Definition of three projects using Mindstorms. Projects scope (a concept introduced during the Project management lessons) were based on Fig. 2.

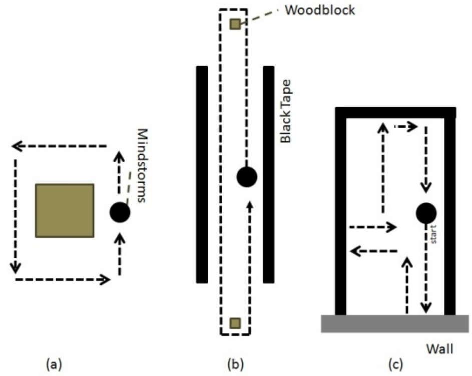

Fig. 2. Projects scope using Mindstorms

Figure 2 (a) presents the scope of project 1. In this figure, Mindstorms, represented by the circle, must go around a wood block. Figure 2 (b) represents the scope of project 2. According to this Figure, Mindstorms must go around two wood blocks and should not cross the black tape. Finally, Fig 2 (c) represents project 3, in which Mindstorms must touch one wall a return back to the initial position following the arrows – notice that by detecting the black tape, Mindstorms must change its route.

5. Definition of the development process. The process was divided into two activities: design and implementation. These activities were carried out by the students during the development of the project. The design activity has as an entry artifact the scope of the project. The exit artifact for this activity is characterized by the project specification document (see Table III). By using this artifact, the students configure (based on the scope – see Fig. 2) Mindstorms sensors and actuators parameters. Finally, it is important to highlight that the project specification document is characterized as an implementation activity entry artifact. This activity's exit artifact is the program to be embedded in Mindstorms (see Figure 3).

It is also important to emphasize that action 5 – development process definition, is based on action 1 – introduction of the concepts related to software process. Concepts such as activities, tasks, entry and exit artifacts and skills were characterized in action 1.

[2] YouTube Channel New Planet School. The video was translated into Portuguese and presented to the students in a traditional classroom.

6. Project development - action designed by the students with the supervisions of teachers (150 minutes). During the development of the project, the students must carry out planning and control activities. During the planning, the students create the WBS - Work Breakdown Structure (PMBOK) and estimate the necessary time and cost to execute each work package (see Figure 4). It is important to highlight that the students must develop 2 out of the 3 projects. During the development of the first project, the students do not have any information in the historical basis of the project to develop a consistent plan, which leads them to overestimate the time and cost for its execution. During the planning of the second project, however, the students have information in the historical basis, which leads them to develop more realistic estimates (see Table VII).

TABLE III SPECIFICATION PROJECT DOCUMENT

Sensor or Actuator	Parameter	Parameter Configuration
Medium Motor	On for Seconds	Second
	Power	75
	Second	4
	Port	A
Large Motor	On for Seconds	Second
	Power	75
	Second	4
	Port	D

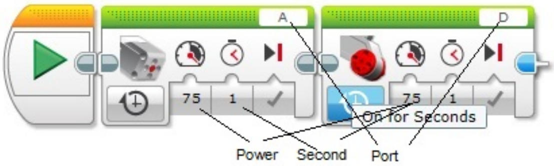

Fig. 3. Program to be embedded in Mindstorms

7. Students Evaluation. During this action, after the development of the project based on action 6, the students prepare a formative evaluation. The evaluation is composed by questions inherent to software process and project management (see questionnaire in Table IV). Action time: 25 minutes.

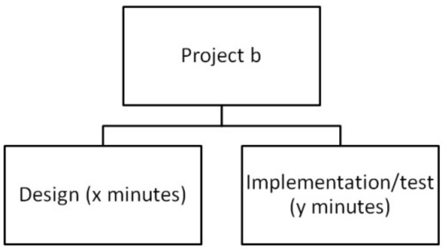

Fig. 4. Work Breakdown Structure (WBS) used in the planning activity

It is important to mention that the questions presented in Table IV were also used during the evaluation of the students who participated in the experiments from 2010 to 2012, who worked under the traditional approach.

8. Evaluation of the Teaching and Learning Process. During this action, the students, after having developed the project based on action 6, answer a questionnaire on the application of Mindstorms to the teaching and learning of Software process and project management (see Table V). It is important to highlight that the questions focus on extremely important variables, which help the internalization of any type of knowledge, stimulus, satisfaction and consolidation [12]. Action time: 25 minutes.

TABLE IV. STUDENTS EVALUATION

As a software project manager, you must estimate the time and cost for the execution of project X. Proponent X made the project scope available. Your company has a historical basis with 3 projects developed. The scope of project X is similar to the projects stored in the basis. Based on this information, define the strategies you used to establish the time and cost for the project. A software production company has a defined process. The activities of this process involves: 1- Requirements elicitation (tasks: mapping of key users and interviews with users). 2- Software projects (tasks: mapping of the functional model and mapping of the data model). 3 – Implementation. 4 - Test (tasks: define test cases, collect test data, test and report) . Construct a Software Project WBS that uses all activities and tasks of company X

TABLE V. EVALUATION OF THE TEACHING AND LEARNING PROCESS

Do you agree that the use of Mindstorms promoted greater stimulus to help students follow the lessons on software process and project management? What's your level of satisfaction with Mindstorms during the learning of software process and projects development concepts? Do you agree that the software project management concepts were consolidated during the execution of the projects using Mindstorms?
Answers to these three questions were characterized by the Likert scale (5- very high, 4- high, 3 – medium, 2- low, 1- very low)

V. RESULTS MAPPING

In the previous section, the authors presented the implementation of 8 actions to validate the application of Mindstorms to the teaching of software process and project management.

Among the actions presented, it is possible to highlight initially two of them: the evaluation of the students (7) and the evaluation of the teaching and learning process (8).

The evaluation is characterized as formative and the questions included in this evaluation are presented in Table IV. The evaluation was conducted together with the students during the experiments from 2010 to 2014 (see Table II). After the evaluation, the authors of this paper, characterized as teachers, corrected it and consolidated the results in Table VI. It is important to emphasize that Table VI presents only the results from the evaluations conducted using Mindstorms in the teaching and learning of process and project management.

Table VI shows that 68 students participated in the experiment, 88.2% answered question 1 correctly (see Table IV), i.e., the students consulted the projects historical basis as part of their planning strategy.

In regards to question 2 (Table IV), the rate of correct answers was 82.4% (see Table VI). The students constructed an WBS correctly.

Some points stand out in Table VI, where 90% of the students from the Software Engineering Course answered question 1 correctly whereas among the students from the

Graduate Program this percentile was 91.7% and among the participants from the software production sector, this value reached 100%.

In regards to question 2, it is possible to verify that the students from the Systems Analysis Course and Computer Engineering went over 90% of correct answers.

TABLE VI. STUDENTS EVALUATION MAPPED RESULTS

Course	Sem.	Q1	%Q1	Q2	%Q2	Qtde.
High School (HS)	6	3	75	3	75	4
Software Engineering (SE)	1	18	90	15	75	20
Systems Analysis (SA)	6	14	87,5	15	93,8	16
Computing Engineering (CE)	1	10	83,3	11	91,7	12
Graduate Program in Computing (GPC)	1	11	91,7	10	83,3	12
Company from the Production Sector (CPS)		4	100	2	50	4
Total		60	88,2	56	82,4	68

Sem. - Application school semester. Q1- Question 1, Q2 – Question 2. %Q1- Percentage of correct answer for Q1. %Q2 – Percentage of correct answers for Q2. Qt – Number of students who participated in the experiment.

The high levels of correct answers to questions 1 and 2 are intimately related to the implementation of action 6 – project development. This fact was detected during a meeting with the participants of the experiments.

During this action, the students under the supervision of the teachers, created the Work Breakdown Structure and estimated the necessary time and cost to implement each work package (vide Figure 4). It is important to emphasize, once again, that the students must develop 2 out of the 3 projects mapped in Figure 2. During the development of the first project, the students have no information in the historical basis to develop a consistent plan (concept required in question 1 of the test) – see Table IV), which leads the students to overestimate time and cost. However, during the planning of the second project, the students already have information in the historical basis, which helps them raise more realistic estimates. This can be attested by the information in Table VII and Figures 5 to 10.

An analysis of Table VII shows that Group 1, formed with 4 high school students (HS) estimated for Project 1 (Pro 1), 25 minutes for the execution of the project activity and 5 minutes for the implementation of the activity. Project activity execution real time was 14 minutes, a difference of 11 minutes. Activity Implementation real time was 2 minutes, a difference of 3 minutes. The last column of Table VII shows the sum of these differences: 14 minutes.

For Project 2, group 1 planned 20 minutes for the execution of the project activity which was realized in 16 minutes, a difference of 4 minutes. For the execution of the implementation activity, the difference between the planned and the realized was 2 minutes, a total of 6 minutes (see Table VII). The differences between planning times and projects execution for all groups in all courses can be visualized in the last column of Table VII and Figures 5, 6, 7, 8, 9, and 10.

An analysis of Tables VII and Figures 5, 6, 7, 8, 9, and 10 shows that:

- Four projects were accurately estimated and executed (difference between the planned and the realized was equal to zero)
- Eleven projects were estimated and executed with a difference classified by the - 1 to 5 minutes interval.
- There are 17 projects in Table VII whose estimations were made based on historical information, in 64.7% of them the difference between the planned and the realized was between - 1 to 5 minutes.
- Sixteen out of 17 project estimated based on historical information had a reduction in their overestimated time.

TABLE VII. PLANNING: PLANNED VERSUS REALIZED

Experiment/Project/Group	Project (minutes)			Implementation/test (minutes)			Pr(P-R) + I(P-R)*
	P	R	P-R	P	R	P-R	
HS – Pro 1 – Group 1	25	14	11	5	2	3	14
HS – Pro 2 – Group 1	20	16	4	3	1	2	6
SE – Pro 1 – Group 1	35	12	23	45	15	30	53
SE – Pro 1 – Group 2	30	10	20	45	10	35	55
SE – Pro 1 – Group 3	35	7	28	50	11	39	67
SE – Pro 1 – Group 4	30	20	10	60	35	25	35
SE – Pro 1 – Group 5	40	22	18	60	35	25	43
SE – Pro 2 – Group 1	14	15	1	16	15	1	0
SE – Pro 2 – Group 1	10	10	0	18	16	2	2
SE – Pro 2 – Group 1	13	12	1	13	13	0	1
SE – Pro 2 – Group 1	22	21	1	35	32	3	4
SE – Pro 2 – Group 1	24	24	0	35	34	1	1
SA – Pro 1 – Group 1	120	17	103	90	17	73	176
SA – Pro 1 – Group 2	20	15	5	65	21	44	49
SA – Pro 1 – Group 3	90	90	0	30	22	8	8
SA – Pro 1 – Group 4	30	10	20	20	18	2	22
SA – Pro 2 – Group 1	20	15	5	25	22	3	8
SA – Pro 2 – Group 2	15	15	0	23	23	0	0
SA – Pro 2 – Group 3	10	11	1	22	21	1	0
SA – Pro 2 – Group 4	21	20	1	15	15	0	1
CE – Pro 1 – Group 1	15	5	10	80	25	55	65
CE – Pro 1 – Group 2	60	10	50	140	15	125	175
CE – Pro 1 – Group 3	30	5	25	30	15	15	40
CE – Pro 2 – Group 1	15	6	9	15	5	10	19
CE – Pro 2 – Group 2	10	10	0	10	10	0	0
CE – Pro 2 – Group 3	8	8	0	13	7	6	6
GPC – Pro 1 – Group 1	20	7	13	100	26	74	87
GPC – Pro 1 – Group 2	55	9	46	40	14	26	72
GPC – Pro 1 – Group 3	35	9	26	33	14	19	45
GPC – Pro 2 – Group 1	7	6	1	26	13	-13	14
GPC – Pro 2 – Group 2	10	9	-1	14	14	0	-1
GPC – Pro 2 – Group 3	9	8	1	14	14	0	1
CPS – Pro 1 – Group 1	25	10	15	80	25	55	70
CPS – Pro 2 – Group 1	20	18	2	15	12	3	5

P: Planned R: realized P-R : Planned –Realized
Pr : Project I : Implementation/test
*Sum of the differences between Planned minus Realized for Project activities (Pr) and Implementation (I)

Therefore, based on these results, it is possible to conclude that the projects planning concept with a historical basis tends to be internalized naturally by the students. Question 1 from the formative evaluation (Table IV) corroborates directly with this finding.

During the evaluation of the teaching process, the students that participate directly in the experiment were invited to answer 3 questions (using the Likert scale) mapped in Table V. The authors of this work collected the answers given by the students in Table VIII.

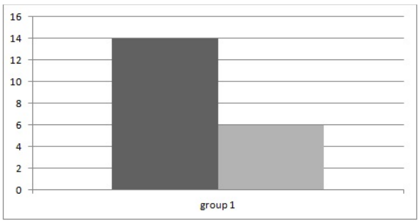

Fig. 5. High School – sum of the differences between planned and realized for Project 1 (14 minute) and Project 2 (6 minutes)

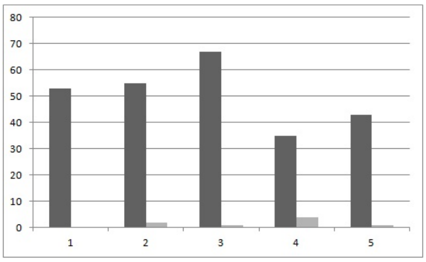

Fig. 6. Software Engineering - sum of the differences between planned and realized for Projects 1 and project 2 – the class was divided into 5 groups of 4 students.

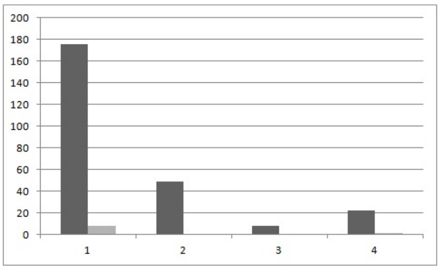

Fig. 7. Systems Analysis and development – sum of the differences between planned and realized for Project 1 and project 2 – the class was divided into 4 groups of 4 students.

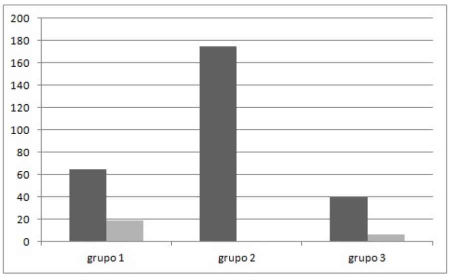

Fig. 8. Computing Engineering – sum of the differences between planned and realized for Project 1 and Project 2 – the class was divided into 3 groups of 4 students.

By adding the percentiles obtained for 4 – high and 5 very high (Table VIII), it can be verified that:

- Mindstorms promoted greater stimulus to follow the lessons on software process and project management in 92.3% of the students.
- The level of satisfaction brought by the use of Mindstorms during the learning of software process and project management concepts was 95.6%.
- The Mindstorms provided solidification about concepts project execution to 97.1% (see Figure 2).

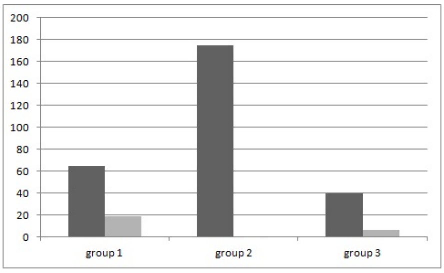

Fig. 9. Graduate Program in Computing - sum of the differences between planned and realized for Project 1 and Project 2 – the class was divided into 3 groups of 4 students.

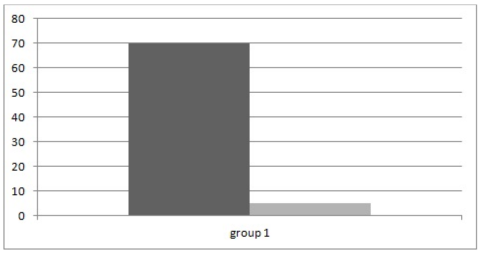

Fig. 10. Company from the Production Sector - sum of the differences between planned and realized for Project 1 (70 minutes) and Project 2 (5 minutes) .

TABLE VIII. TECHING AND LEARNING PROCESS EVALUATION MAPPED RESULTS

Questions (Table V)	Likert Scale				
	5	4	3	2	1
Stimulus generated by the use of Mindstorms	50 73,5%	13 19,1%	4 5,9%	1 1,5%	0 0%
Level of satisfaction by using MIndstorms	54 79,4%	11 16,2%	2 2,9%	1 1,5%	0 0%
Consolidation of software process and project management concepts using Mindstorms	53 77,8%	13 19,1%	1 1,5%	1 1,5%	0 0%

VI. CONCLUSIONS

Problems related to software process improvement and project management is connected to knowledge transfer. The development of an environment that promotes the internalization of abstract knowledge of process and Project management can contribute to possible solutions to these problems.

In the literature, the Mindstorms is applied in teaching and learning computer programming. This paper provides a differentiated approach; the Mindstorms is used for teaching and learning process and management of software projects. The concepts inherent in computer programming are addressed however they aren´t characterized as the main focus of the paper.

In this context, the objective of this work was to apply Mindstorms as a motivating object to promote the internalization of knowledge about software process and project management. This is not a recurring topic in the literature (see section II).

To validate the application, the authors of this work developed 8 experiments from 2010 to 2014, with the participation of 154 students (86 in Phase A, without Mindstorms, 68 in Phase B, with Mindstorms – see section 1). Five experiments were carried with graduate students, one with undergraduate students, one with high school students and one in a company from the software production sector.

With the execution of the experiments, it was possible to verify that:

1. In the two experiments carried out in the traditional way – without the use of Mindstorms as the teaching and learning object - from 2010 to 2012, the concepts connected to the software process and project management were absorbed by 64.86% of the students (see Section 1).
2. With the use of Mindstorms, 88.2% (an index superior to that pointed out by the previous item) of the students absorbed naturally the concepts related to software process and project management, mainly under the perspective of activities planning (using the historical basis of projects) and execution (see Table VI). This finding deals directly with problems inherent to project planning appointed by the CHAOS report. This fact collaborates to qualify positively question 1 (see section 1).
3. 82.4% (higher index than that appointed by item 1) of the students absorbed the concepts related to the institutionalization of a software process by using the project analytical structure as the basis (see Table VI). This finding deals directly with problems inherent to the creation and institutionalization of software processes appointed by the CMMI report. This fact collaborates to qualify question 1 positively (see section 1).
4. Stimulus, satisfaction level and consolidation of concepts promoted by the use of Mindstorms as a teaching and learning object was classified as 5 - very high level and 4- high level (Likert scale) for 95.1% of the participants (see Table VIII). This finding qualifies question 2 positively (see section 1).

Teachers who work directly with subjects related to software process and project management attested that students that participated in the experiments showed better fluidity in relation to these concepts in the following semesters.

Mindstorms was also a motivating factor for about 90% of the participants (see Table VIII). It is also emphasized that motivation in the teaching and learning process is intimately connected to stimulus, satisfaction and consolidation, variables related to the evaluation of the teaching and learning process [12].

The realization of the experiments attested that software process and project management concepts are internalized by the participants, regardless of their stage (high school, freshman year at college, senior year at college, graduate school and company worker). These data can be found in Tables VI and VII.

After the experiment, the company from the production sector started to plan its projects using the historical basis concept, improving significantly the level of corrected cost and deadline estimates.

Finally, the authors found that the model used to develop this work presented in Fig. 1 can be applied to the teaching and learning of any content. In this work, the model was instantiated by the use Mindstorms as an object for the teaching and learning of software process and project management.

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