Edutainment Robotics as Learning Tool

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Abstract. Many constructivist technologies allow students to improve problem-solving strategies and learning in educational settings, encouraging teamwork and creativeness. Hence, in didactic contexts, the building, design and programming of Lego® MindStorms™ robots entertain students, stimulating technological and social factors. In this paper, we investigated the knowledge acquisition of a Lego Robotics system in University students, who had to create a robot able to take part in a race and avoid an obstacle placed in an arena. The learners' documentation of each phase of the task (reports, schemes, photos and videos) was analyzed as cognitive fingerprints of subjects' mental activities.

Keywords: Learning and Instruction; Lego; Edutainment Robotics; Cognitive strategies; Constructivism.

1 Introduction

Over recent decades, a number of robot construction kits for edutainment applications have been designed to improve and increase interaction between users and robotics artifacts [1], [2], [3], [4]. As Lund and Pagliarini assert, [5] some robots have a static morphology (e.g. Furby), while others have one which is variable (e.g. Lego® MindStorms™, FischerTechnic robot). The robots with a variable morphology, give the user the opportunity to build, plan and program different kinds of robotics artifacts. This latter Edutainment Robotic kit has been built in accordance with learning principles derived from Piaget and Vygotskij's theories [6], [7], [8] of cognitive development, as revised by Papert [9], which portray learning as the acquisition or 'construction' of knowledge through observation of the effects of one's actions on the world [10]. The constructivist approach promotes a kind of learning in which the educator does not transfer information, but is rather a facilitator of learning, leading the working group, and so the learner enhances his/her knowledge through the manipulation and construction of physical objects.

With regard to specific artefacts, numerous researchers endorse Robotics as an educational tool [11], [12], [13], [14], [15], [16], [17], with a quantity of literature devoted solely to using the Lego MindStorms kit [18, 19, 20, 21], at levels ranging from primary school to University [22], [23], [24], [25], [26], [27], [28]. There are reports of improved performance in Mathematics, Physics, and Engineering courses resulting from educational Robotics projects [29], [30], although most of the evidence is based on the reports of teachers achieving positive outcomes through individual initiatives [31].

Z. Pan et al. (Eds.): Transactions on Edutainment III, LNCS 5940, pp. 25–35, 2009.

Moreover, Johnson [32] argues that Robotics offers special educational leverage, because it is multi-disciplinary field involving a synthesis of many technical topics, including Mathematics and Physics, Design and Innovation, Electronics, Computer Science and Programming, and Psychology. Research results suggest that the pedagogical value of robots lies in making them work, through using or extending knowledge to identify problems, and argues that robots are a particularly motivating technology because they are concrete, complex, and relate to deep human needs.

In effect, by constructing physical agents together with the code to control them, students have a unique opportunity to tackle many central issues directly, including the interaction between hardware and software, space complexity in terms of the memory limitations of the robot's controller, and time complexity in terms of the speed of the robot's action decisions. Furthermore, the robot theme provides a strong incentive to learning because students desire to see the success of their invention [12]. Moreover, many researchers underline the positive results in the rehabilitation of autism and cognitive deficits using interactive robots [33], [34].

Another application for Edutainment Robotics is represented by RoboCup [35]. The World-Wide RobCup Championship is a large international competition that aims at involving all sorts of research in Robotics and Artificial Intelligence. It has been developed with the initial idea that the stimulus of competition encourages the integration of different technologies which, once optimized for the engaging and pleasant game of football, may be transferred to significant, practical problems for industry. The RoboCup Championship involves participants in the challenges of competition, as well as in the development of educational skills [36], [37]. Finally, it can be stated that robots are a particularly motivating technology and that the use of Robotics tools in teaching contexts offers the opportunity to build a bridge between entertainment and education [38].

In this paper, we present the results of an empirical research project with university students the purpose of which was to investigate cognitive strategies using the Lego MindStorms robotics kit.

The paper is organized as follows. In section two, we present a description of the research objective. In section three, we describe the subjects. The robot laboratory organization is described in section four. In section five, we describe the materials used. Section six focuses on methods of results analysis. Finally, in sections seven and eight we present analysis of the results and some conclusions.

2 Objectives

Our research aimed at investigating the learning process by using Edutainment Robotics. In particular, we analyzed the cognitive abilities of the University students involved in the Lego robot construction, related to:

- Planning strategies – students are expected to use the Constructopedia (a guide with different examples of robot Lego projects) to plan their robots, by modifying little functional parts of their artefacts. For example, students could use little wheels if large wheels prevented good performance.
- Programming strategies – students should learn to define and manage robot behavior in relation to the final task.

- Students' use of different strategies to complete the task and how these strategies influence the results.

3 Subjects

Twenty-eight students, aged from 19 to 21 and enrolled in an 11-week Robotics laboratory program at the University of Calabria, were divided into 6 groups. From an individual interview, we found that none of the subjects were familiar with the concepts of Educational Robotics or the Lego MindStorms kit.

All of the students were enrolled to the first year of the Humanities degree course and attended the Cognitive Psychology course. The aim of the course was to present an overview of Cognitive Psychology, its findings, theories and approaches. The course was divided into two sections. The first introduced central cognitive processes such as perception, memory, learning, language, reasoning and problem solving. The second focused on Artificial Intelligence and explained the reproduction of human behaviour in artificial agents such as Robotics artefacts.

4 Robotics Laboratory Organization and Assignment

The Robotics laboratory program comprised 22 hours of activities, two hours a week for 11 weeks: preliminary lessons covered elementary concepts of Robotics, the Lego MindStorms kit, the visual programming environment and the Robotics Invention System (RIS). During the laboratory activities, each group had to design, build, program and test the performance of its own robot. The final task was to realize a robot able to cross an arena in order to take part in a race.

The groups had to describe and report on the robot planning, the resolution of the problems encountered in the construction of the robots, the programming methodologies, the number of tests and the dividing up of work within the group. In particular, they had to document each phase of the work through reports, schemes, photos and videos.

At the end of the laboratory activities, a race divided into two rounds took place. Each robot had two minutes to complete its performance in each round.

5 Materials

The MindStorms kit (Fig. 1) includes over 700 traditional Lego pieces, the RCX (Robotics Command System), infrared transmitter, light and touch sensors, motors, gears, and a visual detailed building guide or Constructopedia™. The building guide provides students with direction in their building of working robots, as well as inspiration for more complex robotic inventions models.

The core of the Robotics Invention System is the RCX "brick", a microcomputer that can be programmed using a Personal Computer. The RCX receives input from the environment through sensors, it processes data, and then it transfers the output to the motors. Each user may program the robot, using a specific programming language and a personal computer. The next step is to download the program into the RCX memory using an infrared transmitter or Transceiver. Finally, the robot agent can move in an autonomous way in the environment.

Fig. 1. Lego MindStorms Robotics Invention Systems

6 Method of Results Analysis

We analyzed the reports that students made during their laboratory activities in order to detect the task organization, related to cognitive strategies in problem solving, applying the followings evaluation criteria:

- Work distribution in each group.
- Groups' description of working modalities for task resolution (programming and planning strategies).
- Correctness of programming strategies, related to the results of the robot race.
- The number of programming tests completed before the robot was able to cross the arena.

In particular, the programming analysis methodology pointed out the conceptual aspects of programming, investigating program adjustment in relation to the final task and the cognitive strategies used.

7 Analysis of the Results

From the analysis of the reports, we found that the groups utilized three different typologies of work subdivision:

- The first typology was adopted by three groups. Each member adopted a role in the building work (for example, one person read instructions, another person chose the appropriate piece and others assembled the chosen pieces). All the members programmed the robot.

- The second typology was adopted by two groups. Members did not adopt a fixed rule in building and programming the robot (for example, the same person chose the appropriate piece and assembled it together with the other pieces).
- The third typology was adopted by only one group. Each member adopted a role in building and programming the robot and a leader supervised the work.

Regarding the programming and planning modalities, each group carried out tests to modify the behavior of the robot.

The first group carried out six programming tests (Fig. 2), the second five, while, the third and the fourth carried out four, and the fifth five. The sixth group carried out ten.

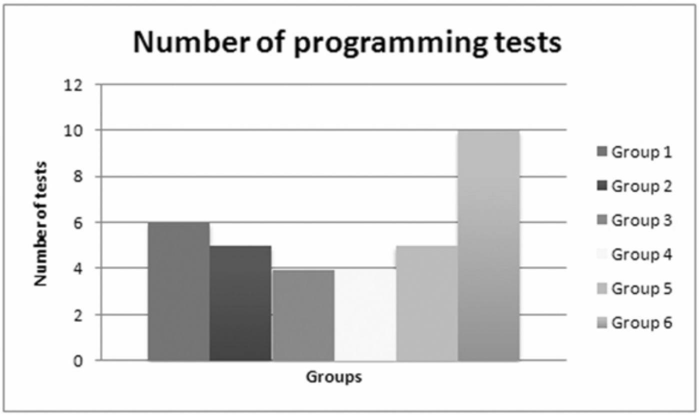

Fig. 2. Number of programming tests carried out before completion of the task

Each group programmed the robot's behaviour correctly. The robots of the first and fourth group obtained a good time in the first round of the race but exceeded the maximum time in the second one (Fig. 3).

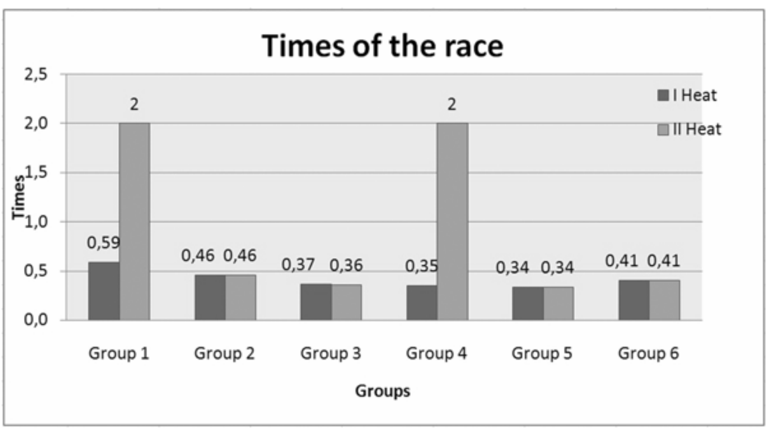

Fig. 3. Times obtained by each group's robot in the two stages of the race

The robots of the first and fourth groups did not complete the race because they exceeded the maximum time in the second stage. Taking into account time achieved for each robot during the rounds, we calculated the mean time, expressed in milliseconds, which ranged from 0,33 to 0,46 (Fig. 4).

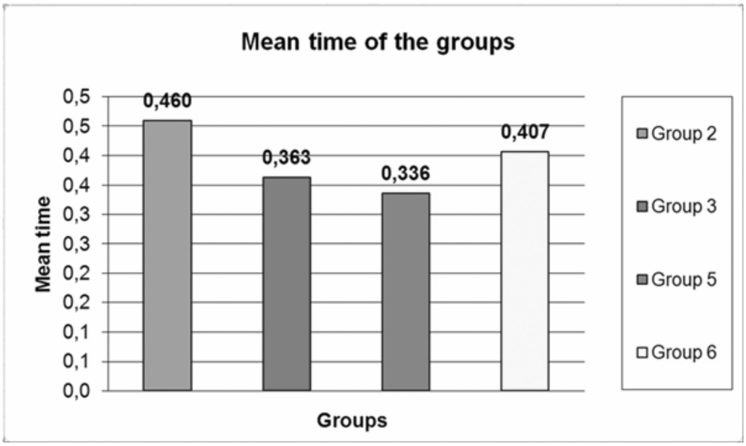

Fig. 4. Mean time in milliseconds of the groups' robots which completed the race

From these results and from the report analysis, we identified two kinds of strategies: strategies orientated towards the task and strategies orientated towards the solution [39].

The groups, which used a strategy orientated towards the task did not test their robot's behaviour many times and focused their attention on comprehension of the task (group 3 and group 4). In fact, in this kind of strategy subjects are skilled at understanding implicit rules quickly, hypothesizing about the trials [40]. In the strategy orientated towards solution, subjects do not analyze the problem but immediately test the possible solution. Groups using this kind of strategy tested the robot's behaviour many times and focused their attention on the goal (groups 1, 2, 5 and 6).

The robot that completed the two rounds and obtained the best time was the robot from group 5 which used the strategy orientated towards solution. Furthermore, we detected three phases in the students' work:

1. **Planning and building of the artefact**. Students plan and build the robot structure (the structure is chosen from amongst the different suggestions in the Constructopedia), acquaint themselves with Lego MindStorms and learn to use the pieces of the kit. Manipulating various objects within the kit allows students to organize their work and to discover the importance of the various pieces and connections. Many students were observed to be using their own personalised design; they enriched an original structure or built it with simply its more essential elements so that it would not be weighed down (Fig. 5).

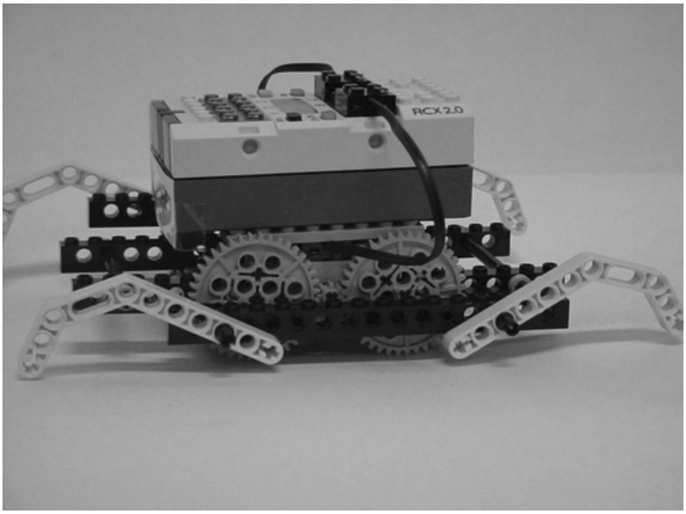

Fig. 5. An example of a robot built by a group of students

2. **Behavioural programming**. Students learned a programming language that allowed them to control the artificial agent's behavior (Fig. 6). The Figure 6 show the program realized by students to control robot behavior. In this program students use two touch sensors to control the robot movement within the arena during the competition. This program is very simple but it is functional to achieving the final objective.

Programming was divided into two sections (basic programming and sensor programming); the key concepts of this phase included: performance in sequence following the instructions, logical order of the commands, and use of conditional expressions, loop and debugging.

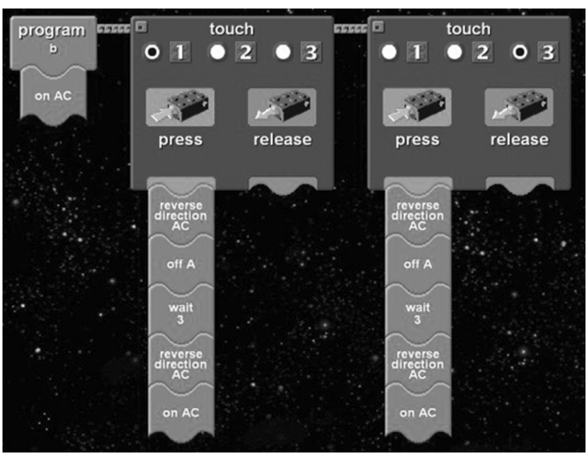

Fig. 6. An example of a program prepared by a group of students

3. **Check**. Students checked the results of their work, in particular the physical structure and the algorithm that controlled the robot's behavior. They also decided on modifications to improve the time taken to cover the path in the arena (Fig. 7).

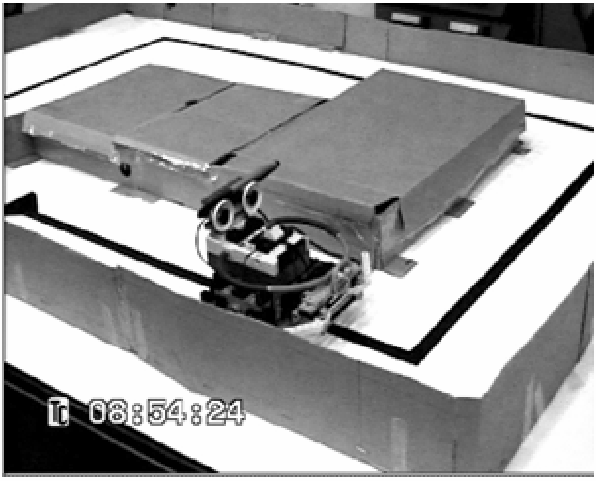

Fig. 7. The competition arena with Lego MindStorms robot

The best times in the final race were obtained by groups three and five, which had adopted the second typology of work subdivision (without fixed roles, collaborating for every task). These groups carried out a small number of tests in building and programming the robot, paying close attention to task comprehension in a problem-orientated strategy.

8 Conclusions

In this work we focus on the cognitive strategies adopted by University students attending a Robotics laboratory program, working in an Edutainment setting with the Lego MindStorms kit. We analyzed the students' reports on the teamwork during laboratory activities, and we gathered information on the subjects' working modalities during the activities of building and programming basic robots. First of all, we detected three different typologies of work subdivision: each member adopted a role in the building work and all programmed the robot; members did not adopt a fixed rule in building and programming the robot; each member adopted a role in building and programming the robot and a leader supervised the work. We then found that the use of robots stimulated students to explore their own knowledge in a critical way and to share it within the group, and that the activity of realizing an artefact took place through precise phases. These phases were:

1) Planning and building of the artefact, related to problem identification and objective definition, collection and production of ideas, problem conceptualization. During the building and manipulation phases, a fundamental role was played by the perceptive and behavioral functions and by the affordance that the elements of the kit suggested to the subjects. As they progressed with the work, students advanced in the learning process and became able to explore, arrange and recombine, in different ways, the material structures and the creative ideas in order to realize the final artefact.

2) Behavioral programming, in which students detected problems, hypothesized and applied solution strategies. In this way, they were able to enrich their work through new details, looking at different thinking modalities; in particular, in planning strategies students divided the problem into many parts and elaborated each part from the particular to arrive at a general solution. This phase was strictly related to the check phase.

3) Check, in which subjects evaluated the realization of the artefact and decided on the need to go back to the building phase, to the programming phase, to both, or rather to search for new ideas.

Thanks to the results of this analysis we can affirm that the Robotics laboratory stimulated students with regard to problem finding (the subject identifies and formulates the initial idea or the problem to solve), problem solving (the subject elaborates and explores some possible solutions in order to reach the objective) and checking procedures (the subject evaluates the artefact's properties from functional, planning and behavioral points of view). The repetition of each of these phases allowed the subjects to modify and improve the structure and this reflected their mental model of the artefact in relation to the assignment.

We underline that the students followed the basic Constructopedia, instructions and prototype figures for the building of the robot, but the final look of each artefact differed because of their using creativity. Moreover, each group programmed the robot's behavior correctly.

In conclusion, Edutainment Robotics stimulates students to change their artefacts, to modify them for their specific needs and to choose the best strategy to accomplish their tasks. In this view, the use of robotics artefacts in didactic contexts stimulates students to analyze processes and information selection, to observe and to experiment the consequences of their behavior. In this way, students get used to problem solving, are encouraged to work collaboratively and co-operatively and to improve their listening to others. In general, this construction of knowledge and the reflection on the process is essential for the retention and application of learning in every field.

Edutainment Robotics creates a cognitive bridge between educational aims and concrete experience, encouraging in the students, at different levels, the acquisition of new skills in an engaging setting.

References

1. Eguchi, A., Reyes, J.: Engage and Motivate Non-Computer Science Major Undergraduates Using Educational Robotics. In: McFerrin, K., et al. (eds.) Proceedings of Society for Information Technology and Teacher Education International Conference, pp. 2572–2576. AACE, Chesapeake (2008)

2. Miglino, O., Lund, H.H., Cardaci, M.: Robotics as an educational tool. J. of I. Lea. Rese. 10(1), 25–48 (1999)
3. Sklar, E., Parsons, S., Azhar, M.Q., Andrewlevich, V.: Educational Robotics in Brooklyn (short version). In: Proceedings of the AAAI 2006 Mobile Robot Workshop (2006)
4. Balogh, R.: Basic Activities with the Boe-Bot Mobile Robot, In: Proceedings of conference DidInfo 2008, FPV UMB, Banská Bystrica, Slovakia (2008)
5. Lund, H.H., Pagliarini, L.: Edutainment Robotics: Applying Modern AI Techniques. In: Proceedings of International Conference on Autonomous Minirobots for Research and Edutainment, AMIRE 2001 (2001)
6. Piaget, J., Inhelder, B.: La psychologie de L'enfant, P.U.F., Paris (1966)
7. Piaget, J.: L'epistemologia genetica, Roma-Bari, Laterza (1971)
8. Vygotskij, L.S.: Storia dello sviluppo delle funzioni psichiche superiori e altri scritti, Giunti, Firenze (1974)
9. Papert, S.: Constructionism: A New Opportunity for Elementary Science Education. MIT: Media Laboratory-Epistemology and learning group, Cambridge (1986)
10. Papert, S., Harel, I.: Constructionism. Ablex Publishing, Norwood (1991)
11. Denis, B., Hubert, S.: Collaborative learning in an educational robotics environment. C. in Hum Beha 17, 465–480 (2001a)
12. Kumar, D., Meedan, L.: A robot laboratory for teaching artificial intelligence. In: Daniel, J. (ed.) Proceedings of the ACM SIGCSE symposium, pp. 341–344. ACM Press, New York (1998)
13. Nostrand, B.: Autonomous robotics projects for learning software engineering. In: Proceedings of IEEE (2000)
14. Weinberg, J.B., Engel, G.L., Gu, K., Karacal, C.S., Smith, S.R., White, W.W., Yu, X.W.: A multidisciplinary model for using robotics in engineering education. In: Proceedings of the 2001 ASEE AnnualConference and Exposition (2001)
15. Martin, F.: Circuits to control: learning engineering by designing Lego robots, PhD. thesis. MIT Press, Boston (1994)
16. Bertacchini, P.A., Bilotta, E., Gabriele, L., Pantano, P., Servidio, R.: Investigating cognitive processes in robotic programmers developed by children in educational context. In: Roccetti, M., Syed, M.R. (eds.) Proceedings of international conference on simulation and multimedia in engineering education/Western multiconference on computer simulation (ICSEE/WMC 2003), SCS, Orlando, pp. 111–116 (2003)
17. Bertacchini, P.A., Bilotta, E., Gabriele, L., Servidio, R., Tavernise, A.: Investigating Learning Processes Through Educational Robotics. In: Proceedings of II ASLA, Australian online conference, 8-26 Maggio (2006a)
18. Klassner, F., Anderson, S.: Lego MindStorms: Not just for K-12 anymore. IEEE Robotics and Automation Magazine (2003)
19. Bertacchini, P.A., Bilotta, E., Gabriele, L., Pantano, P., Servidio, R.: Apprendere con le mani. Strategie cognitive per la realizzazione di ambienti di apprendimento-insegnamento con i nuovi strumenti tecnologici. Franco Angeli, Milano (2006b)
20. Marcinkiewicz, M., Kunin, M., Parsons, S., Sklar, E., Raphan, T.: Towards a methodology for stabilizing the gaze of a quadrupedal robot. In: Lakemeyer, G., Sklar, E., Sorrenti, D.G., Takahashi, T. (eds.) RoboCup 2006: Robot Soccer World Cup X. LNCS (LNAI), vol. 4434, pp. 540–547. Springer, Heidelberg (2007)
21. Goldman, R., Azhar, M.Q., Sklar, E.: From roboLab to aibo: A behavior-based interface for educational robotics. In: Lakemeyer, G., Sklar, E., Sorrenti, D.G., Takahashi, T. (eds.) RoboCup 2006: Robot Soccer World Cup X. LNCS (LNAI), vol. 4434, pp. 122–133. Springer, Heidelberg (2007)

22. Ma, Y., Williams, D., Lai, G., Prejean, L., Ford, M.: Integrating storytelling into robotics challenges that teach mathematics. Paper presented at the Society for Information Technology and Teacher Education International Conference (2008)
23. Moundridou, M., Kalinoglou, A.: Using LEGO Mindstorms as an Instructional Aid in Technical and Vocational Secondary Education: Experiences from an Empirical Case Study. In: Dillenbourg, P., Specht, M. (eds.) EC-TEL 2008. LNCS, vol. 5192, pp. 312–321. Springer, Heidelberg (2008)
24. Petrovic, P., Balogh, R.: Educational Robotics Initiatives in Slovakia, Teaching with Robotics, SIMPAR (2008)
25. Petre, M., Price, B.: Using robotics to motivate 'back door' learning. E. and Inf. Tech. 9(2), 147–158 (2004)
26. Arcella, A., Bertacchini, P.A., Bilotta, E., Gabriele, L.: Progettare il comportamento di un robot: un esperimento didattico. In: Bertacchini, P.A., Bilotta, E., Nolfi, S., Pantano, P. (eds.) Proceedings of the first Italian workshop of artificial life, Arcavacata di Rende, Cosenza, Italy (2003)
27. Gabriele, L., Arcella, A., Servidio, R., Bertacchini, P.A.: Investigare strategie di problem solving attraverso la robotica: un'esperienza con studenti universitari. In: Baldassarre, G., Marocco, D., Mirolli, M. (eds.) 2nd Workshop Italiano di Vita Artificiale, Istituto di Scienze e Tecnologie della Cognizione, CNR, Roma, Marzo 2-5 (2005a)
28. Gabriele, L., Servidio, R., Tavernise, A.: Acquisire concetti complessi attraverso l'uso di strumenti: un'indagine empirica. In: Atti del Congresso Nazionale della Sezione di Psicologia Sperimentale dell'AIP - Associazione Italiana di Psicologia, Cagliari, settembre 18-20 (2005b)
29. Bers, M.U., Portsmore, M.: Teaching Partnerships: Early Childhood and Engineering Students Teaching Math and Science Through Robotics. J. of S. Edu. and Tech. 14(1), 59–73 (2005)
30. Nagchaudhuri, A., Singh, G., Kaur, M., George, S.: Lego robotics products boost student creativity in pre-college programs at UMES. In: Budny, D., Bjedov, G. (eds.) 32nd ASEE/IEEE frontiers in education conference, pp. S4D-1–S4D-6. IEEE, Piscataway (2002)
31. Yoon, S., Pedretti, E., Pedretti, L., Hewitt, J., Perris, K., Oostveen, R.: Exploring the Use of Cases and Case Methods. J. of S. Tea Educ. 17(1), 15–35 (2006)
32. Johnson, J.: Children, robotics, and education. In: 7th International Symposium on Artificial Life and Robotics (AROB-7), pp. 491–496 (2002)
33. Cardaci, M., Caci, B., D'Amico, A.: La robotica nella riabilitazione di soggetti autistici e con deficit cognitivi, Tecnologie digitali e l'Intelligenza Artificiale al servizio dei disabili, C.I.T.C, Università di Palermo (2004)
34. D'Ambrosio, M., Mirabile, C., Miglino, O.: Uno studio pilota sull'impiego di giocattoli robotici nella riabilitazione cognitiva. In: Bertacchini, P. A., Bilotta, E., Nolfi, S., Pantano, P. (eds.) In: Proceedings of the first Italian workshop of artificial life, Arcavacata di Rende, Cosenza, Italy (2003)
35. Sklar, E., Eguchi, A.: Examining Team Robotics through RoboCup Junior. In: Annual conference of Japan Society for Educational Technology, Nagaoka, Japan (November 2002)
36. Sklar, E., Eguchi, A.: Learning while Teaching Robotics. In: AAAI Spring Symposium 2004 on Accessible Hands-on Artificial Intelligence and Robotics Education (2004)
37. Baltes, J., Sklar, E., Anderson, J.: Teaching with RoboCup. In: AAAI Spring Symposium 2004 on Accessible Hands-on Artificial Intelligence and Robotics Education (2004)
38. Miglino, O., Lund, H.H., Cardaci, M.: Robotics as an educational tool. J. of I. Lea. Rese. 10(1), 25–48 (1999)
39. Lawson, B.R.: How designers think. Architectural Press, Oxford (1997)
40. Arielli, E.: Pensiero e progettazione. La psicologia cognitiva applicata al design e all'architettura, Bruno Mondadori Editore, Milano (2003)