Ingenium: an exploratory research on learning processes specific to robotic labs

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Abstract.

The *Ingenium* project is an exploratory research that investigates the processes of learning in robotics laboratories frequented by students aged between 13 and 19 years with the aim of improve teaching in educational contexts. The study highlights the specific learning processes involved in robotics labs and how they affect positively on overall school performance.

Keywords: Robotics lab – Learning processes – Education contexts – Improve teaching

1. Introduction

The *Ingenium* research project was commissioned by the Fondazione O.M.C. Collegio Vescovile Pio X to the Psychology and Pedagogy Unit, a department of the institution itself handling issues related to study methods, learning and developmental disturbances, systems psychology applied to relations, eating disorders; the unit is moreover involved in school system related research work. The Psychology and Pedagogy Unit is a scientific professional team composed of professionals specialized in disciplines such as psychology, biology, locomotion, art and drama, education, new media, psychotherapy, medicine and social communication. The Unit's pivotal mission is to promote best practices in educational contexts: we believe that it is by increasing the psychological and educational welfare of students, their families and teachers that the overall development of the school system can be fostered.

The *Ingenium* research project was implemented to study the robotics labs that have been in operation for several years at the Fondazione O.M.C. Collegio Vescovile Pio X. The learning outcomes achieved by students during the workshops carried out turned to be remarkable indeed: as a matter of fact, levels of learning with regard to mathematics and physics applied to the workshops proved to be higher compared to results obtained by traditional classroom lessons. Interestingly, it appeared that there were yet undefined factors benefiting the learning process and it was clear that there were significant differences to be traced between a robotics lab lesson and a

Proceedings of 3rd International Workshop
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Riva del Garda (Trento, Italy) April 20, 2012
ISBN 978-88-95872-05-6
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traditional lesson. It was therefore decided to analyze the context of the robotics lab itself and thereby identify the specific variables involved in learning processes taking place.

The research was conducted between October 2011 and January 2012 at the educational facilities of the Fondazione O.M.C. Collegio Vescovile Pio X in Treviso, Italy. The team was directed by Dr Tito Sartori, Head of the Psychology and Pedagogy Unit, under the scientific supervision of Prof. Adriano Zamperini, Associate Professor at the Department of Applied Psychology of the University of Padua. The research team consists of psychologists specialized in learning and educational processes, as well as four training consultants of the *Centro di Terapia Familiare Eidos*, an institute of family therapy located Treviso; the centre is part of the *Centro di Terapia della Famiglia* established by Luigi Boscolo and Gianfranco Cecchin, offering counselling and psychotherapy services to families besides high level training in communication and human relations aimed at professionals.

2. Aim of the research project

The general aim of the project was to gain more detailed knowledge concerning learning processes specific to robotics labs. The paradigm of action-research (Lewin, 1946) was adopted, according to which every act of cognition produces changes in the object of study. In this case, the aim was to give voice to students' actual needs and make sure they would be actively involved, the background assumption being that a new educational model should provide for interactions between teachers and students so as to improve both teaching processes and methodologies applied. Furthermore, a secondary objective of the research was to provide a general methodology for the study of learning experiences with specific features which make them not comparable with traditional educational and teaching methodologies.

Michel Foucault's inaugural lecture, *The Order of Discourse*, held at the Collège de France in 1971, offers a noteworthy element of analysis, where it states that discourse is one of the areas where power is enacted. Discourse is claimed to be ordered by forces imprisoning what the system considers as dangerous, namely what institutions would typically relegate to somewhat invisible, unreachable shadow zones. We do hope that this study will give voice to the actual needs of students: we believe that schools and educational contexts should endeavour to create opportunities encouraging communication between different levels, points of view and human resources.

Based on these premises, the specific objective of the research project was to identify the specific learning processes taking place in robotics lab, pinpointing the cognitive processes that encourage learning, to include learning progresses made by students who usually come across as underperformers.

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2.1 Theoretical framework

The Psychology and Pedagogy Unit of the Fondazione Collegio Vescovile Pio X in Treviso generally has a preference for theories emphasizing the importance of human relationships, the uniqueness of each individual, the centrality of communication processes within a pragmatic approach, infused with systemic and ecological thinking; moreover with an awareness of the complexity of social life and bearing in mind individual freedom.

The theoretical foundations at the core of the service are: Cognitivism and Constructivism (G. A. Kelly, H. Mead, J. Piaget, LS Vygotsky, H. Gardner), current cognitive-behavioral approaches (A. Bandura), Social Constructionism (P. L. Berger - T. Luckmann), Symbolic Interactionism (E. Goffman), the Milan Approach and the systemic-relational perspective (L. Boscolo, G. Cecchin), Narrativism (J. Bruner) and the 'Ecology of Mind' (G. Bateson).

In this study, these theoretical assumptions made us consider as relationships and communication are involved in learning processes of robotics labs. Indeed we believe that the individual mind and subjective learning processes are the result of a complex network of interactive processes. That's why we took into account the institutional frameworks (staff and the principal) and the different levels of relationship concerned. The general systems theory considers valid the following logical principle: the simplest element (individual learning process) is explained by the more complex phenomenon (network of relationships between subject and environment).

2.2 Research Methodology

The research carried out was of an exploratory type and for this reason a cautious approach, i.e. open to different possibilities, was adopted. At first, no hypotheses could be rejected with regard to the attempt to understand learning processes that could possibly develop during robotics lab workshops. In this sense, the approach was viewed as a funnel: the assumed starting point would be "zero knowledge" of the subject and the research would follow a bottom-up direction. The object of study would have to metaphorically speak for itself before the team would venture complex assumptions. At a later stage, the same object of study was examined using the Unit's theories as a frame of reference and the process would follow a top-down direction as a result. By adopting this recursive logic procedure, specific research tools for studying the processes of learning within the robotics labs could be gradually developed.

The initial research hypothesis was that in the robotics labs specific learning processes are developed and that they are different from those that develop in a normal learning context. We also believed that these processes influence positively student learning.

The first phase of the research consisted in environmental observations during the robotics lab workshops. Within a systemic-relational perspective, we looked for behavioral and cognitive redundancies. The purpose was to understand whether new cognitive and behavioral interactive rules surfaced compared to ordinary educational settings. We have directly observed the overt behaviors of students in robotics labs. We also recorded the behavioral redundancies, that is those interactive patterns that repeat themselves over time. From these patterns we have identified the implicit rules of interactions of specific to robotics labs. Later, we were able to formulate research hypotheses based on these observations.

Based on data collected during the first observations, initial research hypotheses were developed and it was decided to conduct interviews with 8 people involved in the educational and cognitive processes taking place at the robotics labs. The social actors interviewed were: the member of staff in charge of the laboratories, the school principal, four teachers of mathematics and physics and two coordinators of the institutions involved. The issues investigated during the interviews included: expectations on the results obtainable by the workshops, the perceived differences between the workshops and ordinary lessons, the objectives assigned to the workshops and the general perception concerning the activity itself.

The second phase of the research enabled the team to produce qualitative data, which was then processed by means of hermeneutic analysis. Semantic dimensions were enucleated that turned out to be redundant if compared to various texts processed by the hermeneutic software Atlas.ti. More refined research hypotheses could be inferred from the data collected.

The third phase of the research consisted of a focus group with 12 students taking part in the robotics lab workshops. Students were aged between 13 and 19 and were randomly selected. The focus group investigated relationships between peers as well as between students and teacher and furthermore compared such relationships with those taking place during traditional classroom lessons. It was thereby possible to gain better insight into the students' point of view and refine the initial research hypotheses.

The qualitative analysis of textual material obtained by focus groups enabled comparison with other research data gathered. Seven specific factors involved in the learning processes of robotics lab workshops were subsequently identified, namely Frame, Relationships, Learning, Purpose, Motivation, Metacognition and Class Atmosphere. For each factor, a 5 items Likert Scale was constructed featuring 5 options (each student could select an option concerning the items proposed on a scale from 1 to 5, where 1 represented minimum and 5 maximum agreement). A self-report questionnaire was produced to obtain quantitative data on the learning processes under investigation. The final phase of the research consisted in the distribution of the questionnaire to a random sample of twenty-five students.

The following is a summary of the findings obtained during all four stages presented.

3. Findings

The research involved a total of 45 subjects, including 8 adults in the qualitative interviews and 37 students (12 in focus groups and 25 answering the questionnaire). Students involved were aged between 13 and 19. Findings are here presented according to the seven factors identified.

By “Frame” (first factor) the cognitive basis and implicit rules that pre-order the learning context is meant. In this specific case, three levels of frame hierarchy were taken into consideration. The first one defines the micro robotics lab (students and workshop premises). The second frame is referred to as mesosystem, formed by the interactions between teachers and institution administrators . The third institutional level is the so-called macrosystem, generated by interactions between the management and students' families. It was noticed that there is a connection missing between with the mesosystem and the other two levels. In particular, the analysis focused on what students believe about the priority that the key figures belonging to the three systems (director, school coordinator, teacher, staff member in charge of workshop, parents) assign to the workshop activity itself. It appears that the most fragile level (lower priority) of the entire education system is that of the teachers (mesosystem). This finding was also confirmed by verbal reports.

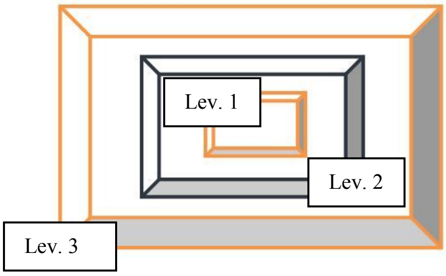

Fig. 1. This graph represents in the form of frame the three levels of the system that we analyzed: micro (level 1), medium (level 2), macro (level 3). The second level is critical.

The relationships between participants in the robotics lab (second factor) were analysed and compared with normal learning contexts, to understand if there significant differences emerged between the two relational contexts and whether such processes affect learning at all. Surprisingly, students stated that peer relationships are similar to those experienced in ordinary contexts (frontal lessons), but what significantly changes is the relationship with the teacher, perceived to be more open and available to facilitate the learning process.

From this point of view, the personal teaching style of the teacher in charge seems not to have a bearing on the actual outcome: what really makes the difference is the setting of the learning process instead, which turns out to be a key factor because of the resulting enhanced involvement of students. Another significant aspect is that students recognize the importance of teamwork: they clearly say that working in smaller groups is much better than in the usual context of ordinary learning, with one large group interacting with the teacher.

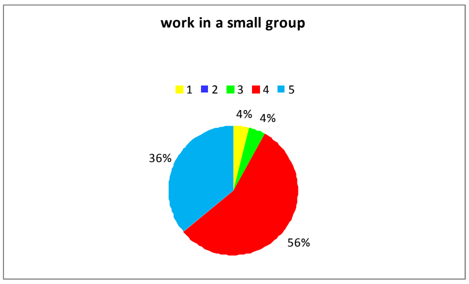

Fig. 2. Number 1 is for a minimum agreement and 5 is for a maximum agreement. This graph represents students' perceptions about the benefits of working in small group, from the point of view of learning.

A relational context of the group as such seems to develop, where students are not "simply in a group" but a cybernetic mind takes shape as a result of knowledge shared and in connection with one another: students in fact are encouraged to collaborate and pool their cognitive, cultural and emotional resources.

The third factor under examination was the learning process. We identified five types of learning: cooperative learning (based on the dynamics of collaboration between students), deductive learning (in which the general rules are applied to specific procedures), experiential learning (based on the trial and error method), intuitive learning (where specific procedures are used to abstract general rules), observational learning (based on observation and subsequent imitation).The aim was to understand how different learning approaches were relevant to the workshop activities their level of importance was gauged. The graph below features learning styles revealed by workshop activities.

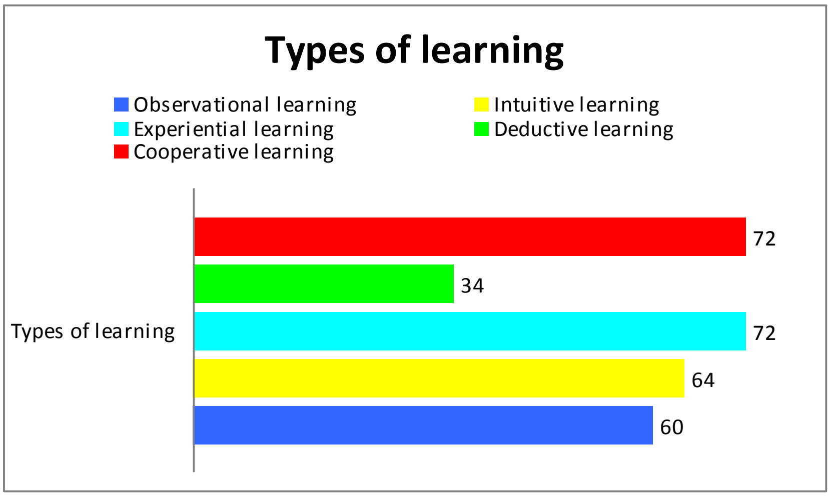

Fig. 3. This graph represents students' kinds of learning: cooperative (72%), deductive (34%), experimental (72%), intuitive (64%), observational (60%). The different kinds of learning are coexistent. The importance attributed to the different kinds of learning is different.

Among the objectives of the research was to investigate the reasons that encourage students to attend robotics labs (fourth factor). 96% of subjects interviewed said they attend workshops to obtain tangible results, possible through the construction of a robot. The same number of students are motivated to participate in the workshop for the pleasure of discovering and inventing. Contrary to the team's initial assumptions, the aim of improving their school results did not appear to be relevant. This data suggests that motivation processes involved are those of intrinsic type (i.e. related to a person's intentions and internal value-gratification).

Motivation was the fifth factor considered: all students involved say they have a high motivation to participate in robotics labs. 64% of the subjects claimed to be totally motivated and highly motivated for the remaining 36%. In addition, attending robotics labs has shown to increase the overall motivation in studying, 64% of participants (32% quite agree, 24% very much; 8% totally agree).

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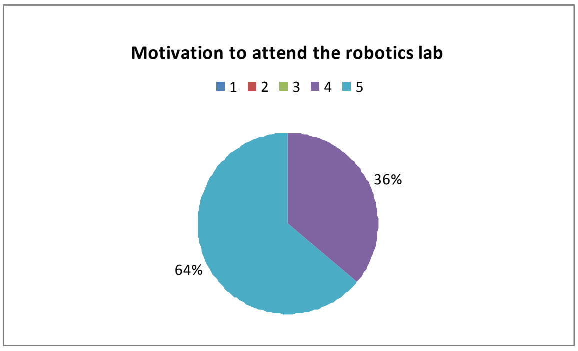

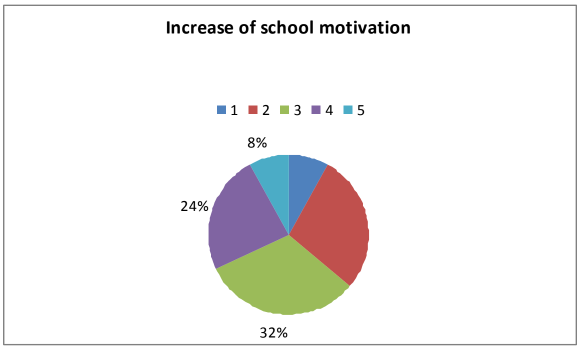

Fig. 4. Number 1 is for a minimum agreement and 5 is for a maximum agreement. The first graph represents the motivation to attend the robotics lab. The second graph represents the participation in the robotics lab affects the motivation to participate in school.

In particular, 80% of subjects involved said that their motivation depends on the ability to freely choose whether to join the activities in robotics and the ability to turn their learning into tangible outcomes and products. This confirms results reported for factor 4.

Meta cognition is the sixth factor: 88% of students report having developed meta-cognitive skills through workshops in robotics, and in general confirmed their ability to reflect on their learning processes. This evaluation increases significantly if related to ordinary problem solving processes (96%) and also to general school knowledge (96%). This type of analysis is relevant to claims by Bateson (1972) with regard to learning processes, in particular when the student learns to reflect on his own learning in order to modify and improve it.

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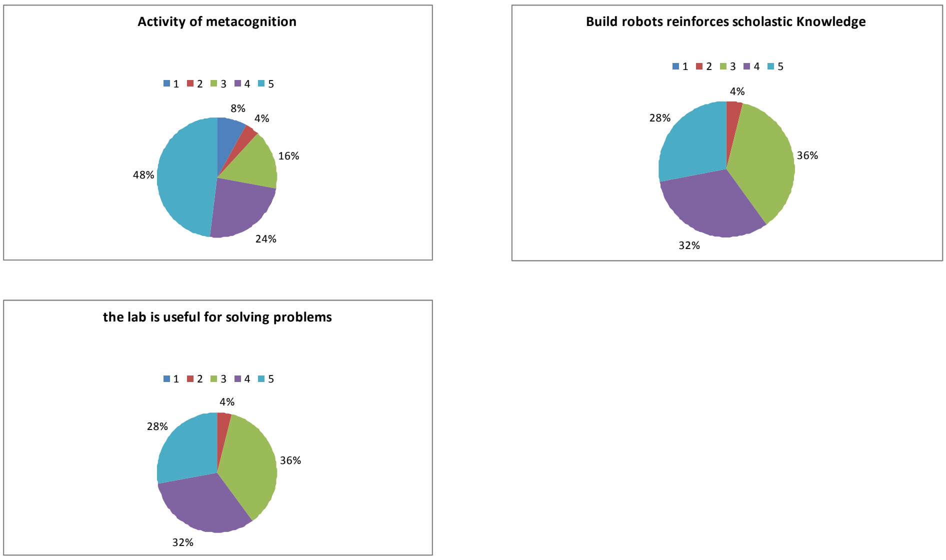

Fig. 5. Number 1 is for a minimum agreement and 5 is for a maximum agreement. The first graph represents the importance of metacognitive processes during the workshops. The second graph represents the influence of metacognitive processes in problem solving skills. The third graph represents how the influence of the processes of learning acquired during the workshop reinforce the school knowledge.

The last factor under examination was class atmosphere, which refers to the perception of pleasure regarding time spent in the educational environment and with reference to internal relations. The totality of the participating students (100%) reported experiencing a positive atmosphere during the lab hours, in particular through the positive relationships between peers as well as with the teacher.

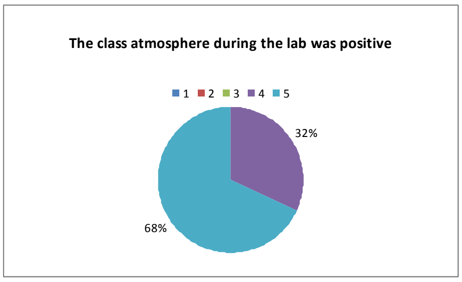

Fig. 6. Number 1 is for a minimum agreement and 5 is for a maximum agreement. The graph represents the class atmosphere during the lab.

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We believe that during certain times of the workshops, students experienced the so-called flow (M. Csikszentmihalyi, 1975), i.e. when a person is fully immersed in an activity and experiences a sense of total involvement, focusing on the objective, feeling intrinsically motivated, optimistic and derives satisfaction from performing the task.

3.1 Conclusions and Future Prospects

Through this exploration we identified interesting aspects regarding the development of educational workshops and more generally, indications have emerged as to how to facilitate learning processes and dynamics. In particular, the data analyzed proves that both the educational context and the student-teacher relationship as such bear significant importance, even more than the teacher's personal characteristics. The outcome is therefore that the context needs to offer students the opportunity to experience teamwork and peer-to-peer collaboration, and small groups promote better learning opportunities compared to large groups. Indeed one of learning situations that students seem to favor is cooperative learning.

Another significant mode is the experimental-learning type: laboratories are more effective because students can learn through trial and error, and most of all they can convert their theoretical knowledge into tangible results. Making mistakes, from this perspective, is no longer a problem: the student's mistake becomes, on the contrary, a useful piece of information promoting learning. All these factors seem to reinforce students' intrinsic motivation and therefore increase the level of active participation in the workshops.

Aspects that need to be addressed and improved concern the connections between the various levels of the system, in order to promote a teaching style shared by all social actors involved. Finally, findings of the research presented suggest that we try to investigate and understand how the distinctive characteristics of the robotics laboratory can be generalized and extended to other school subjects, thereby enhancing student performance in other areas of education.

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