Study of Educational Impact of the LEGO Dacta Materials – INFOESCUELA – MED

Preface

When I was asked to write a short preface for this report my first reaction was to feel honored and delighted for two reasons. First, I consider the INFOESCUELA project to be an excellent piece of work on world standards quite independently of the fact that it was done in a developing country. And second, seeing educational excellence in developing countries encourages me in my belief that at the end of the day it will be countries that proudly see themselves as driven by a need and a desire for development who will lead the shaping of the learning environment of the digital age.

But as I try to write the text I am faced with a serious problem: there is too much that I want to say. Of course, this fact in itself reflects positively on the quality of the work. The well structured way in which it was carried out and the extensive collection of data gives the project an exceptional status for practical educational practitioners as a model to be followed and for theorists as food for very deep thought. If indeed one makes that distinction. Anyone who knows me would understand that it goes against the grain of my fundamental beliefs to suggest that any model be copied literally; an essential component of excellence in educational practice is a large dose of personal creativity by the educators. This means that every educator should also be a theorist and innovator. What I would really like to do is to discuss the many ways in which this project could provide a context for teachers as well as students to learn creatively. But that would require more than a preface. I will do it somewhere else and confine myself here to one aspect of the results obtained by this project that might contribute most powerfully to the liberation of creativity in education.

Some of the learning results shown by the INFOESCUELA research are more easily understood than others. Thus most teachers would be pleased but not surprised to hear that students who had explored principles of physics by building LEGO constructs showed improved understanding of physics. What many would find more surprising is that the students improved their performance in areas far removed from any directly obvious connection with the constructs, for example in Spanish. Perhaps the most important implication of the results of this research is that it shows that it is not necessary to “teach to the test” in order to get quantitatively measurable learning results!

I stress this point because everywhere in the world the shadow of “The Test” hangs over educational innovation. Calling it in question could be the most liberating action for change.

Professor Seymour Papert
MIT Media Lab

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Introduction

The project INFOESCUELA with LEGO Dacta materials is being carried out in schools all over the country. Thus, we are interested in researching its impacts on the educational system. For that purpose, and taking into account the previous experience of the Education Ministry and the IST Wernher von Braun, we undertook this independent research in order accurately to know the impacts generated from the work using this material.

This research project aims at studying the pedagogical effects caused by the application of LEGO Dacta materials in different schools of the country. For that purpose, we relied on two groups of study in order to make comparisons. One of them is called control group (CG) formed by schools, which have not been subjected to the experimental treatment (work with LEGO Dacta) and the other called experimental group (EG), which was represented by schools which have participated pedagogically with the LEGO Dacta proposals and technological materials. In such sense, we followed both groups to be equivalent regarding their educational, social – demographic and linguistic characteristics. These groups used different educational and psychological tests. Likewise, we filled out data formats, and polled principals and teachers of the participating schools.

On the other hand, the study wants to characterise the impact of the LEGO Dacta material in the current school culture. For that purpose, we developed focus groups with teachers, students and parents from the schools, which currently work with the LEGO Dacta material. This project stage enabled us to know the expectations, resistances and attitudes regarding the material.

It is also important, that the project acquire a character of a cost – effectiveness study. Due to that, we took samples of the LEGO Dacta materials in different schools in order to analyse its level of deterioration as years go by, in order to estimate the durability of the material.

Ivan Montes Iturrizaga

Acknowledgements and a short introduction to the INFOESCUELA Project

The INFOESCUELA Project as well as the study of the impact of the LEGO Dacta materials is the results of several years' work and the necessary persistence to do something nobody has ever done before.

The INFOESCUELA Project was started in 1996 with a pilot project for 12 primary schools. The objective was to introduce technology in primary school. The main product used for the project was LEGO TC Logo, a combination of LEGO bricks, motors, lamps and sensors and the Logo software developed by Dr. Seymour Papert.

This solution required the use of computers from 1st to 6th grades, which made an expansion of the project fairly expensive. In 1997 the Ministry of Education, LEGO Dacta A/S and IST. Wernher von Braun agreed on a new line of products based on a progression, where computers were introduced only in 5th and 6th grades (please see product description).

In 1997 and 1998 the INFOESCUELA Project was expanded and by autumn 1998 it was implemented in a total of 130 schools throughout Peru.

Several studies had shown that there was a significant difference in the skills of the INFOESCUELA students compared to students from ordinary schools. However, to get an unquestionable proof of the impact, it was decided to make a large-scale study, which was impartial and approved by an internationally acknowledged institution.

In October 1998 the group of scientists headed by Dr. Seymour Papert at the Media Lab, Massachusetts Institute of Technology (MIT) agreed on supporting a series of quantitative tests provided that qualitative observations were a part of the study as well.

The INFOESCUELA Project and the study would no have existed, if it had not been for the support of the following people and organisations. We should very much like to thank:

- The Peruvian Ministry of Education for implementing and developing the INFOESCUELA Project particularly the ministers Eng. Domingo Palermo and Dr. Ignacio Garcia Escudero.
- Ivan Montes Iturrizaga, educational psychologist and responsible for the study
- Dr. Seymour Papert and his staff at the Media Lab at MIT for their supervision and guidance
- The Ponificia Catholic University of Peru for analysing the durability, the wear and percentage of losses of the LEGO Dacta elements
- The 14 schools, its teachers, schoolmasters and all 1,653 students, who participated in the quantitative tests.
- The teachers, students and parents who participated in the nine focus groups.
- Economist José Linares Gallo, Director of IST. Wernher von Braun, the representative of LEGO Dacta in Peru and author of the program for using the technological materials in the classrooms of the INFOESCUELA Project.

LEGO Dacta A/S

Co-operating entities in the Study of Educational Impact of the LEGO Dacta Materials.

To perform this study, different entities have participated in the co-operation, supervision, and accreditation. In this context, we will briefly describe the levels of participation that each individual has had.

Centro de Investigaciones de Servicios Educativos – CISE (Center of Investigations and Educational Services)

The Project of Peace Education and Culture of CISE of the Pontificia Universidad Católica del Peru has participated as an independent entity in the application of all instruments for the educational measuring and in the supply of data formats. Also, they carried out the inventory of the LEGO Dacta elements and the sampling from the different sets for the later analysis of durability. It's important to mention that in this stage of the project, 18 specialists from the faculty of Education – PUCP have participated. This group was linked to the project above mentioned. On the other hand, a representative of this project has participated in the verification and certification of the database together with engineer Daniel Arestegui from the project INFOESCUELA.

Centre of Innovation and Development

For the analysis of durability and wear of the LEGO Dacta elements, we have relied on the expertise from the Centre of Innovation and Development of the Department of Engineering – PUCP. In this section, sampling of elements by the researchers of the Project of Peace Education and Culture of CISE – PUCP were analysed.

Ministry of Education from Peru

In the stages of process verification and supervision, Daniel Arestegui, a member of the project INFOESCUELA, has participated in representing the Ministry of Education. Specifically, he was in charge of accessing schools, verifying the sampling, verifying and certifying the database and other processes implied. It is important to mention his appropriate and efficient collaboration. It has only been possible make the project thanks to the auspices and support of the Ministry, National Direction, Kindergarten and Primary Education.

Pedagogical Institute of Monterrico

In the stage of marking and data entry to the SPSS software v. 7.5, we have relied on the participation of CODE '98 of the Pedagogical Institute of Monterrico. In this case, we have to mention that the Co-ordinator of the Marking Process, Mrs. Marinella Herrera Tanaka has also participated in the verification and certification of the database.

MIT of Boston

Dr. Seymour Papert from the Massachusetts Institute of Technology (MIT of Boston) has participated as the accrediting expert of the process and measuring instruments. At the end of the project, consultant visited us. She is a representative of the MIT and was in charge of locally supervising the processes used in the study and the instruments applied. Ms. Lygeia Ricciardi also visited some of the schools included in the study.

Executive Summary

The result of the study clearly indicates that the students from the experimental group have fulfilled their school activities successfully due to the use of the LEGO Dacta material. In all three grades the EG gained better percentages of achievement than the CG in the tests of mathematics, technology, Spanish and codification. Likewise, it is shown that regarding the pedagogical self-esteem, the students from the EG obtained higher results than the CG, what would be indicating a positive impact of the materials on the personal level. In other words, the students from the EG feel that they can reach different educational aims and get around all kinds of difficulties on the school level.

Finally, it is important to highlight that for students, teachers and parents studied, the LEGO Dacta material has favourably changed their perceptions regarding the pedagogy. Likewise, it is important to highlight the role played by IST Wernher von Braun in communicating, training of teachers and developing pedagogical materials to optimise the use of the educational material.

Conclusions

1. There are significant differences which favour the EG in all performance and psychological tests applied.

2. The significant differences encountered are wider in mathematics and technology. These areas are on which the greater impact of the program is shown.

3. Significant differences were not found between the work of boys and girls.

4. Although, the program has favourable impact on all grades and aspects measured.

5. Although, children from the EG have used the material only for a year, we can speak of significant positive impacts. In that respect, we assume that the effect would be greater and accumulative as years go by. In other words, the differences between EG and CG would be wider every time.

6. The self-esteem of teachers and students involved is highly influenced within the three grades. Significant differences in favour of the EG were discovered.

7. Although there are significant differences within all grades and tests applied, the Spanish area has the less impact.

8. In the focus groups, the positive perceptions of the program and the wish that this program remain, as years go by were shown. Teachers, parents and students have emphasised the positive effects within the intellectual, motivational and affective social area.

9. Parents and students state, that the teachers are not capable of handling teamwork in the classroom. This causes monopolising of the use of elements by the class leaders and reduces the possibilities of manipulation by shy students.

10. In other cities we observed, thanks to the use of LEGO Dacta material, that the breaches between the schools in Lima and the schools in other cities in the country are getting shorter. We have observed schools in Arequipa, Cajamarca and Trujillo within the EG which had better results than schools in Lima. This could be confirmed in later studies and investigations.

11. We have observed, within the focus groups made in large schools with many students, that the amount of material received was not enough due to the high number of students per classroom.

Recommendations

1. To reinforce the teamwork of children concerning the technological learning to other study areas starting with mathematics.

2. To improve the training programs, to support with literature and audio-visual material for teachers and students (increasing the number of sets according to the need of schools), because it seems that the lack of sets is limiting a better performance of the children.

3. To benefit from the help and interest already shown by the parents, as well as, to perform emotional and social work with them. The aim is to enable the parents to understand what it is about and what their children will achieve with the projects.

4. The LEGO Dacta material has the great advantage that the results of the work and the students' effort are shown directly and concretely. This is a characteristic, which has to be valued and developed with children, parents and teachers.

5. To explore the effect of LEGO Dacta in the Personal Development area in detail. This implies especially the following aspects:

    - Child's self-perception (self-concept, self-esteem)
    - Group relationships and interactions, in pairs and familiar relationships.

    We have observed that the effect on these relationships is positive.

6. To go into depth with future investigations of the intellectual cognitive changes of the students who have worked with LEGO Dacta programs. Especially, within the areas of thinking, intelligence, creativity and imagination.

Background of the study

Having reliable and valid data of the educational processes and educational results can turn into a mechanism of great force and legitimacy to make decisions of educational policies. From this point of view, the assessment of educational processes is always a useful element for the education policy and management, above all, in countries that must optimise the assignment of their resources.

Thus, it does not surprise that it is even more demanded that the pedagogical innovations have to be accompanied by an evaluating component. This explains, for instance, what was said in the paragraph 15 of the aide-mémoire written by the Head of the Ministry of Education, the Improvement Program of the Quality of the Education (MECEP), the Representative of the Ministry of Education and by the evaluating mission of approaches of BIRF in January 1997:

> "Regarding the proposal made by the Education Ministry to incorporate actions for the development of the project –"logo-LEGO" in MECEP, the mission has a favourable answer. It is especially important for us the emphasis of the curriculum head in this project, as an activity of research and development. We suggest that this experiment (----) would be extended (…) strengthening the formative component of this, in order to become possible to identify the cost-effectiveness of the use of logo-LEGO and other variations of pedagogic activities centred in learning by groups and with a large material support (such as LEGO based on the use of learning cards and guides) within a year. We expect a specific response for the development of this activity, together with the respective assessment plan to be developed in urban-marginal areas and in rural areas, principally in extremely poor areas".

The Technical and Pedagogical Report about the Application of the Project INFOESCUELA already mentioned, also cited about the requirement of going into the investigations. What is mentioned in the document is extremely eloquent:

> "It is important to highlight that the assessment presented must be considered as preliminary and basic, since we consider that it is necessary to evaluate the project INFOESCUELA integrally.
>
> We recommend the application of different evaluation instruments, which enable identifying and isolating variables, which in this very first moment, we consider constant.
>
> These instruments should allow identifying the development of the learning among boys and girls, not only regarding the basic skills, but also the new skills which could be developed when we incorporate these technological materials and computer media to the new pedagogical approach corresponding to Primary Education".

This project responds to these demands for knowing the cost-effectiveness of the LEGO Dacta material used in the project INFOESCUELA. And, it is framed within a world concern to give curriculum lines in the scientific technological area to the educational systems.

Selection criteria for the test schools

In general terms, a control group (CG) and an experimental group (EG) form our sample, and there, we have students from 2nd, 4th and 6th grade of primary education. For the school selection, we, firstly, identified schools for the *experimental group* under the necessary criteria in order to guarantee that the *experimental treatment* (work with the material) is being fulfilled precisely and equally among the schools, which participated in the project. We selected the schools, according to the following criteria:

- Schools must have an approximate amount of 500 or 600 students per shift. (In Peru, most schools have two shifts: morning and afternoon).
- Schools must have a Technology Lab with LEGO Dacta materials.
- Schools must have at least a Lab Co-ordinator, who will be in charge of the managing of the LEGO Dacta materials.
- For the inter - learning workshops, teachers must have the LEGO Dacta Teacher's Guide and the student's worksheets, as material for the classroom
- The exposition time of the materials to the students is 12 hours per month.
- Schools must be part of the Project INFOESCUELA with LEGO Dacta materials since 1998.
- Schools must have the complete LEGO Dacta kit assigned to public schools.

After selecting the schools for the experimental group, and using the experience of specialists and social and economic indicators, we selected equivalent schools, but only schools, which have not been benefited with the LEGO Dacta material (Project INFOESCUELA).

14 schools were selected in the following way:

Distribution of the Sample by groups (EG and CG)
Schools and grades of Primary Education

SCHOOL	CITY	GROUP	2ND	4TH	6TH
Jose Olaya Balandra	Lima	Control	41	40	40
83004-91	Cajamarca	Control	40	40	40
Virgen de la Puerta	Trujillo	Control	40	42	40
5040	Lima	Control	41	40	29
3056-Gran Bretaña	Lima	Control	38	40	39
6011	Lima	Control	38	41	40
Sta. Rosa de Lima	Arequipa	Control	35	37	39
Arturo Timoran	Lima	Experimental	33	38	30
Marcelino Champagnat	Cajamarca	Experimental	40	40	40
Ntra. Sra. de Monserrat	Trujillo	Experimental	40	39	31
Ntra. Sra. de Fatima	Lima	Experimental	42	40	40
3094-1 Tahuantinsuyo	Lima	Experimental	40	38	44
6014 Villa Maria	Lima	Experimental	42	41	36
Sta. Dorotea	Arequipa	Experimental	43	50	46
Total			553	566	534

Finally, it is important to mention, that for the selection of the schools for the EG and the CG, specialists from Lima visited other cities in order to guarantee the major homogeneity among each pair of schools. In other words, each experimental school should match a school of the Control Group.

Population Analysis

On a basis of information gathered during the application stage, we can mention that the sampling in the study is presented homogeneously in the distribution intra-inter group: in the experimental and control groups. We can see regarding the variable gender, that in 2nd grade, we have 280 male students and 273 female students. In the sample corresponding to the 4th grade, we have a similar distribution between boys (n = 274) and girls (n = 292). This same trend is observed in the sample of the 6th grade. There, we have 261 male students and 273 female students.

Regarding the variable place in the 2nd grade, we can see that 315 students in Lima, 80 in Trujillo and Cajamarca and 78 in Arequipa, form our sample. There is also a total balance between the experimental and control groups in Trujillo and Cajamarca. In Lima and Arequipa, there are minor differences. At the event of Lima it is 1 individual and in Arequipa 8. In the 4th grade, we have worked with 317 students in Lima, 82 in Trujillo, 80 in Cajamarca and 87 in Arequipa. As well as in the 2nd grade, there is a total balance between the experimental and control groups in Cajamarca.

In Lima and Trujillo, there are minor differences. At the event of Lima, there are 5 individuals, in Trujillo 2. In Arequipa the difference is 13 individuals. For the 6th grade of primary education, we have worked with 298 students in Lima, 71 in Trujillo, 80 in Cajamarca and 85 in Arequipa. There is a total balance between the experimental and control groups in Cajamarca. In Lima, Arequipa and Trujillo, there are little differences. In the event of Lima, the difference is 2 individuals, in Arequipa 7 and in Trujillo 9. In all cases, there is a statistical control, which guarantees the authenticity of the result.

Regarding the variable individual age, we can observe that the distribution of the 2nd grade evidences a concentration in ages 7 and 8, in which it is more concentrated than within the 70% of the cases in each participating city in the study of pedagogical impact. In 4th grade, we can observe that there is, in all cities, an age concentration in ages 9 and 10, in which more than the 70% of this population is located. For the 6th grade, we can observe that there is a concentration in ages of 11 and 12 that reaches the 70% in each participating city.

As conclusion, we can mention that the distribution of our individuals, who form our sample, enables the test application with statistical significance in order to establish the existence of difference between the control and experimental group. In this sense, there is homogeneity in our samples intra-inter groups, which guarantees the authenticity of the analysis.

Test method and reliability

Previous studies and observations note that the pedagogical work using the LEGO Dacta material would be influencing in different cognitive, affective, and psychomotor aspects. In such context, this project is an effort to estimate the possible positive effects of the LEGO Dacta material from an objective and technical point of view and with more experimental controls.

In this framework, we may discern different effects expected due to the use of this material. One of them refers to the establishment of knowledge, notions and intellectual habits in the science and technology field. Also, we expect children that have worked with the material and with the pedagogical guidelines suggested to evidence greater performance levels in the curriculum areas of mathematics (mathematical logic), and Spanish (Integral Communication). Likewise, it is pointed out through the work with this material, the work in groups and the mutual help are encouraged. All these aspects would be influencing in promoting a high pedagogical self-esteem in children due to the type of investigative and manipulative experiences that this material enables.

Due to all the possible effects and impacts – hypothesis of work – we made a series of valid and reliable tests that we have applied to children of the sample. For that purpose, we follow the following technical criteria.

Elaboration of the Test Instruments

After defining and schematising the theoretical aspects that will be reflected in the tests, we summoned specialists in the writing of the questions for the following curriculum areas: mathematics (mathematical logic) and Spanish (Integral Communication). These specialists were in charge of making the questions under a direct supervision of the principal researcher of the project. It is important to mention that these teachers have a wide experience in this kind of work in the National System of Quality Measurement of Consorcio de Centros Educativos Catolicos del Peru.

Once elaborating the questions, the researchers responsible of the project ordered and classified the information by levels of cognitive domain. They improved the items, their alternatives and designed a preliminary format of the test. In this stage, a professional drawer of educational materials graduated in the Escuela de Bellas Artes (Lima) illustrated all tests according to specifications provided by the project staff. At this moment, we began to structure the first version of the tests.

Pilot study of Test Instruments

Once the preliminary tests were done, we began to apply them experimentally to individuals who have the same characteristics of our definitive sample. This experience enabled us to correct graphics, alternatives and to specify the more appropriate verbal instructions for our individuals in study. Likewise, we could determine the average times in the application and the more appropriate application sequence of the instruments.

On the other hand, this experimental application enabled us to determine the validity of the items (item-test correlation) and the reliability of each test by the method of internal consistency known as Cronbach Alpha. The calculation of these psychometrical values has been possible thanks to the reliability analysis module of the software SPSS v 7.5 for PC and IBM.

As we have mentioned before, we controlled the average time for each test. We also gathered qualitative information to improve the test formats and to increase the acceptance levels by children.

The pilot sample was formed by a total of 750 students from the 2nd, 4th, and 6th grade. In this opportunity, we apply the tests of Spanish, mathematics, and technology. Schools that formed the experimental sampling were: Santa Rosa (subsidised urban school), Jose Olaya (urban marginal Public school), Nuestra Señora del Morro (Public – urban marginal school) and Juan Alarco (urban Public school).

After the application, we analysed the data psychometrically. Regarding the validity of the items, we analysed them using the item-test correlation, accepting the item with indicators of more than 0.20. At the event of the reliability, we applied the Crombach Alpha. So, we have the following reliability indexes for the tests:

- For Spanish: 0.83 (2nd grade), 0.80 (4th grade), and 0.83 (6th grade).
- For technology: 0.78 (2nd grade), 0.80 (4th grade), and 0.82 (6th grade).
- For mathematics: 0.79 (2nd grade), 0.82 (4th grade), and 0.7*9 (6th grade)

Basically, the Spanish and technology tests have not been changed, except for the improvement of the graphics and drawings. At the event of mathematics, we had to reduce the number of items, due to the large amount of time, which the experimental application demanded.

This version of the tests was sent to the MIT of Boston and reviewed by Seymour Papert, Professor and Researcher, who sent an endorsement letter regarding the series of tests, which were applied to the EG and CG.

As conclusion, we may mention that our instruments, from the psychometric, educational and theoretical point of view, are valid and reliable in correspondence with the standards and rules required for this kind of tests.

Description of Test Instruments

Mathematics Test

This test is formed by multiple choice items and fill in the blanks' questions based on the official programs in force of the Ministry of Education. This test will explore the fundamental mathematical knowledge and skills for each grade. So, we have the following sub-tests: recognition of quantities, problem and operation solving. Like in the previous case, this test will value the fundamental and significant skills rather than explore the theoretical knowledge about mathematics. The mathematical knowledge to solve proposed problems and the application of the mathematical knowledge to solve daily life situations would be emphasised. There will be tests for 2nd, 4th, and 6th grade of Primary Education.

Spanish Test

The test is formed by multiple choice items and different formats that explore, what is more significant in the official programs of the Ministry of Education. This test will include sub-tests of vocabulary, reading comprehension, image analysis. It is important to mention that this measuring instrument will favour the expressive and comprehensive skills of the language. In this sense, this test will explore the development level of the linguistic processes rather than the theoretical knowledge and information about the Spanish language (grammatical knowledge). We applied test versions to 2nd, 4th and 6th grade of Primary Education. Likewise, we were looking for an instrument, which enables us to ponder the linguistic skills of children, specifically, regarding the processes that imply test comprehension. Based on a text at an elementary level, we elaborated a "cloze" test (fill in the blanks) to know the skills based on the type of words filled in. The test of the 6th grade includes a "cloze" test.

Technology Test

This test consists of multiple choice items. This test will explore knowledge and understanding of technical principles. In this sense, and because we wish to measure the effects of the program LEGO DACTA, no graphical stimulus with a clear reference to the parts or the devices of the material will be used. In this case, we will only use practical problems from the real life. This will prevent the control groups (CG) from being at disadvantage for not knowing the LEGO Dacta material. This test will also include items based on the official programs of the curricular areas of Science and Technology in order to make comparisons between the CG (control group) and the EG (experimental group) based on themes worked in different points of view. There will be versions of the test for 2nd, 4th and 6th grade of Primary Education.

Pedagogical Self-esteem Test and attitudes towards team work

This test consists of items formed by incomplete phrases for the 2nd grade. It seeks to know the children's feeling of auto valuing and skills regarding their daily activities as students (pedagogical self-esteem). Also, for the 4th and 6th grade of primary education, we supplied the self-esteem tests – inventory type – of Cooper Smith.

Codification Test

This test explores the eye-hand codification and some aspects such as psychomotor aspect, rapidity and learning capacity. This test is a sub test of the Intelligence Scale for Children of Wechsler (1974). This aspect measured is very important because there will be the hypothesis, that children exposed to the LEGO Dacta material, would evidence major rapidity and inter sensorial, thanks to the pedagogical manipulative and exploratory experiences.

Graphical presentation of the test results

The students in 2nd, 4th and 6th grades were tested in five categories:

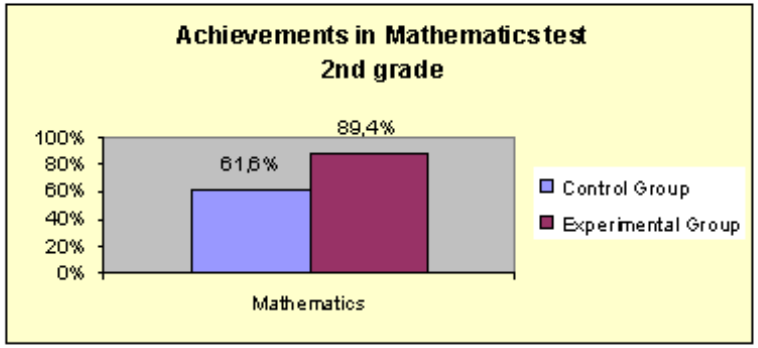
- Mathematics skills
- Technological knowledge
- Spanish performance
- Codification/eye-hand co-ordination
- Self-esteem

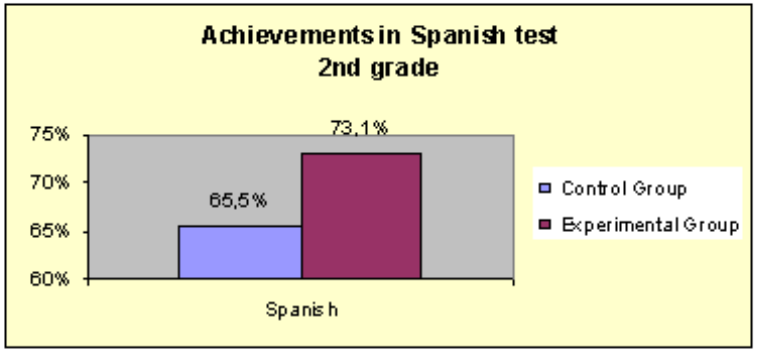
The different colours of the diagrams on the following pages represent each grade.

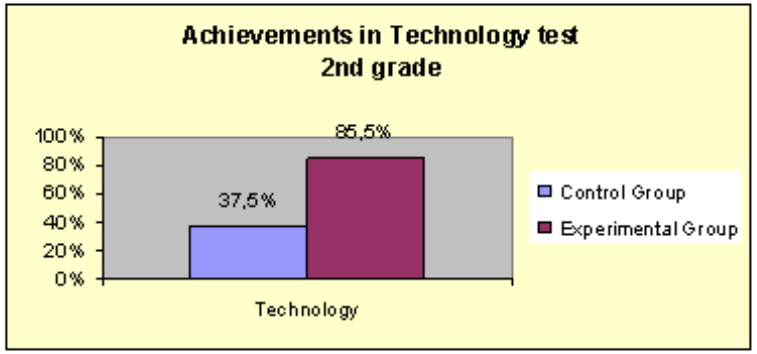
The diagram 'Comparison of test results' shows the difference in percent of the test results of the control group and the experimental group. An example: the test of mathematics skills in 2nd grade shows a score of 61,6% for the control group and 89,4% for the experimental group. This gives the following result: (89,4/61,6)*100= 45,1%.

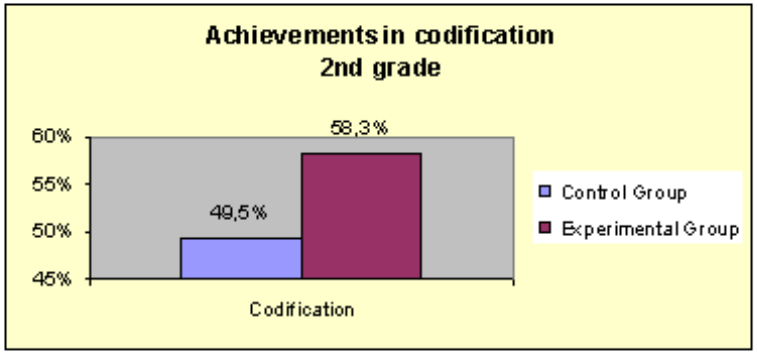
The objective is to show the significant difference between the control group and the experimental group, and the difference between the grades and the different tests.

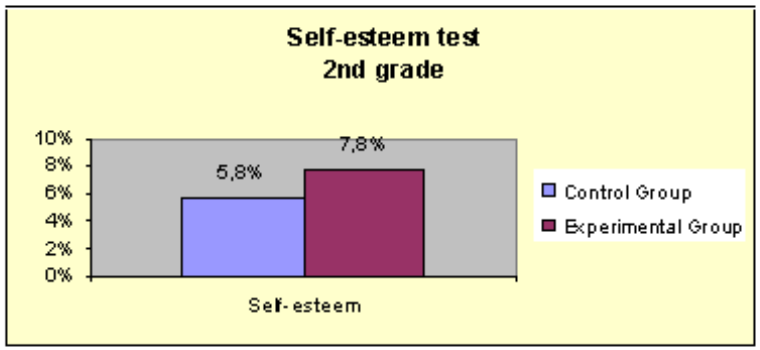
Results of quantitative tests in 2nd grade



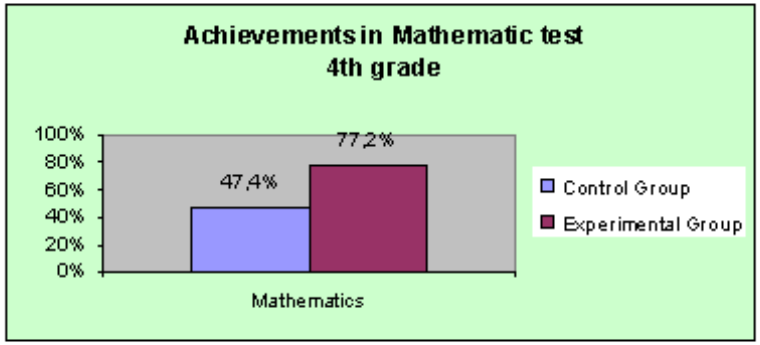


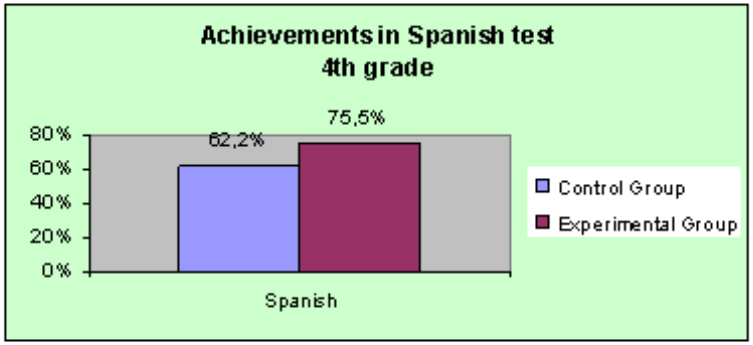


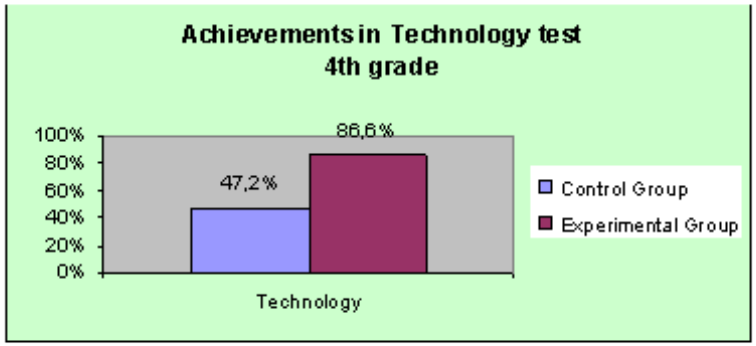


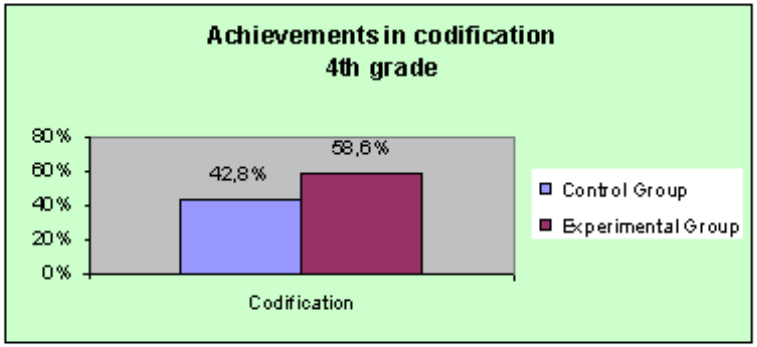


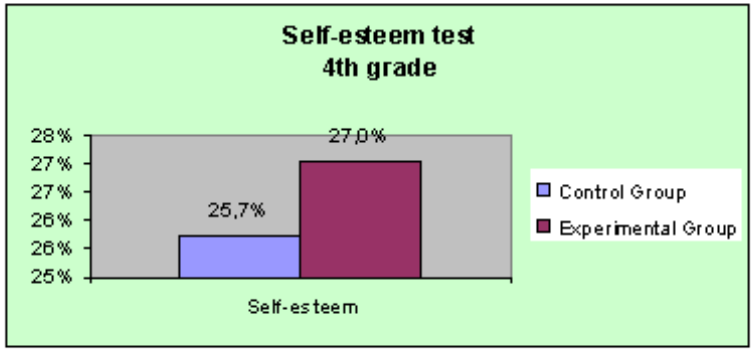
Results of quantitative tests in 4th grade



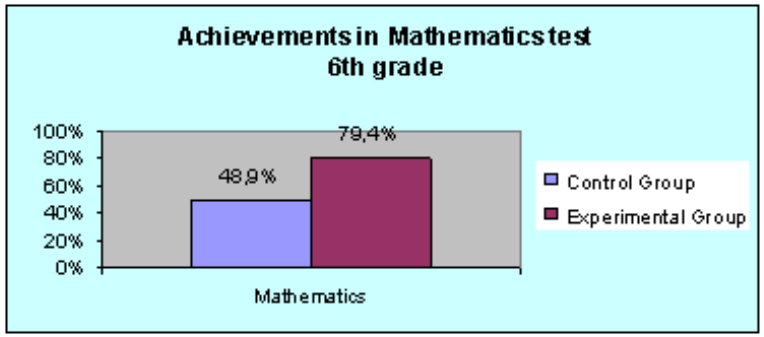


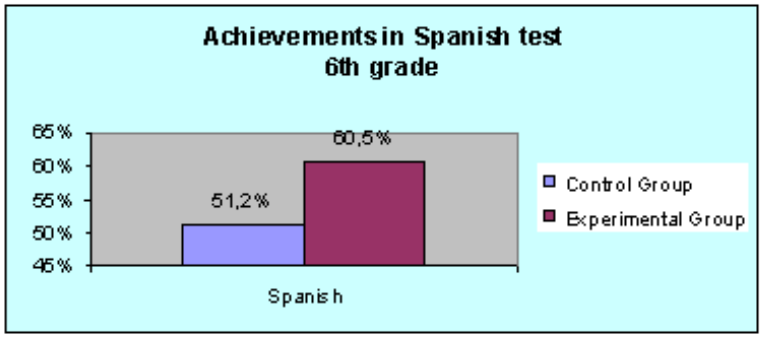


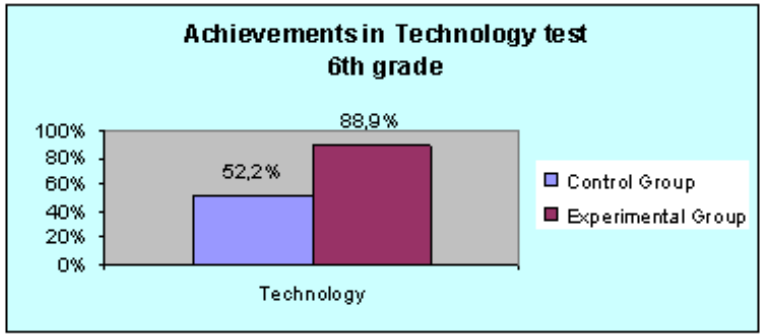


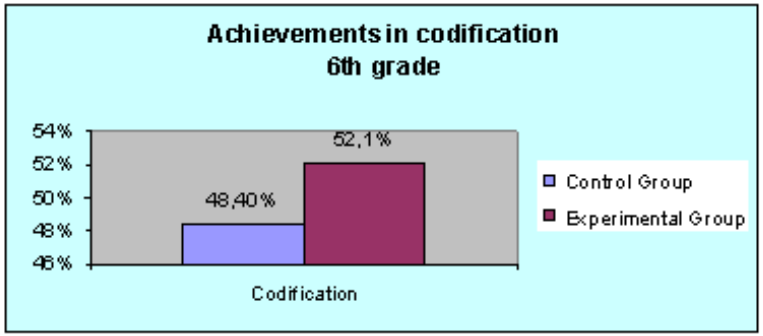


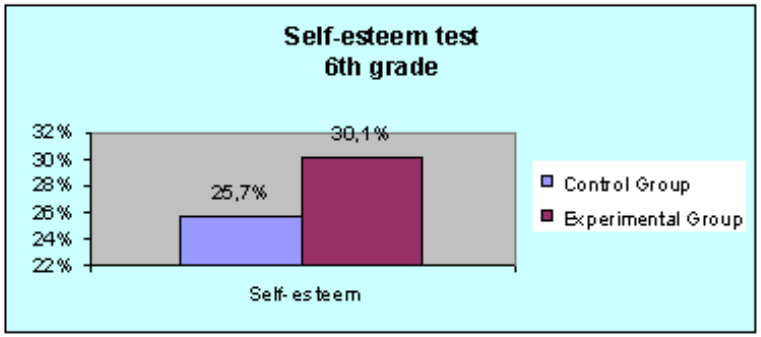
Results of quantitative tests in 6th grade











Comparison of test results

Difference in percent in test results between the EGs and the CGs

Qualitative observations by means of focus groups

In order to supervise the complete study MIT required that qualitative observation was a part of the study.

For that purpose we put together nine individual focus groups: three with teachers, three with students and finally three with parents.

The statements by the teachers, students and parents on the following pages give a clear and honest picture of both the strengths and the weaknesses of the INFOESCUELA Project.

Strengths of the Project Infoescuela with LEGO Dacta materials

According to the teachers

1. **Logical thinking skill / "science consciousness**".
   The teachers agree that the pedagogic work with the LEGO Dacta material encourages the critical, logical and objective thinking of the students. Besides, they say that the contents referring to technology (worked with the material) approach the children to science, giving them a vision much more close to what science and technology are in the present world.

2. **Interest in research**.
   We state that during 1998, the students have expressed steadily a series of concerns and worries about scientific research. As a result, many students have developed the intellectual habit of asking, observing, experimenting and giving practical solutions (based on technological principles) for problematic situations of the daily life. To teachers, the more children worked with the technology contents, the more interested they became in consulting the scientific bibliography. Therefore, it is reported that many children have found the relation between technological research and development.

3. **Development of the creativity and imagination.**
   To teachers the handling and constructive activities provided by the LEGO Dacta material would encourage the child's desire to make his own realisations and expand his imagination and invention in searching for technological devices which solve different social problems. We emphasise in several opportunities, that the LEGO Dacta material does not bore the students since it is appropriate to endless constructions of new models and machinery. In other words, we emphasise the endless possibilities of construction and display of the imagination provided by the LEGO Dacta material.

4. **A very encouraging element for learning.**
   We emphasise that the subjects are most encouraging when it is announced, that they will work with the LEGO Dacta material. In this case, teachers ratify that the principle of the objects handling and the play and learn strategies are the best ways to establish the significant learning.
   Almost all teachers mention that manipulating the material has a positive effect in students at a motivational level. Children, according to teachers, attend the class happier and look forward the moment they will work with the material. Also mentioned are the many possibilities that this material would have in other areas. There was an agreement to mention that LEGO Dacta material could become a support material for almost all the school subjects.

5. **Develop of a communicative personality**.
   According to teachers, the program has influenced tremendously in the development of the students' personality. It is noticed that, those students who before would not talk, now express more freely and keep closer relationships with their classmates. In some way or another the work around the LEGO Dacta material implies communication within the working group. That would encourage the development of inter-learning groups and the consolidation of the work in group as one of the best ways to make an efficient mediation. On the other hand, it has been noticed, the fact that research and searching solutions with others imply a bigger development of the expressive processes both orally and in writing.

Strengths of the Project Infoescuela with LEGO Dacta materials

According to the students

1. **Science consciousness.**

   Students consider that the work of the technology contents using the LEGO Dacta material has encouraged their interest to understand the processes and circumstances of the scientific discoveries. Besides, they emphasise that during the year they could work with the material, they have been interested in reading scientific books, magazines and articles.

2. **Self-assured personality (striking).**

   Children are very self-confident and wish to express their points of view. They emphasise that before working with LEGO Dacta material, the classes were "boring" and did prevent communication among students. In this context, students say that working with the material has given them more self-confidence. They admit that before they were a little afraid of speaking in public, but now they have overcome those problems.

3. **Interest in discovering, will to "assemble and disassemble everything".**

   Children admit that working with LEGO Dacta material has created wish to learn how the different devices and machine work. This implies an intense activity focus on assembling and disassembling several machines or devices. Likewise, they remark that working with LEGO Dacta material has given them the motivation to discover instead of waiting for answers.

4. **A liking for things that they thought was difficult.**

   Physics, science in general. Children say that they have just understood how interesting science is. Furthermore, some children say that before, they were not interested in anything that had to do with physics or mathematics, but that now they are motivated to learn more about those topics. Furthermore they say that working with LEGO Dacta material has helped them facing confidence in other subjects and themes related to social sciences.

5. **Opportunities for the future.**

   Learning technological principles with the LEGO Dacta material prepare the children for the future. They consider that their experience with the LEGO Dacta material will be useful for their professional life. Regarding this, it is important to mention that for students it is very important the handling experience because they say that in the grown-up life almost all of the activities imply the use of technology. They also consider that they have an advantage of other children, who have not been benefited by the project. In other words, they assume that an education using the LEGO Dacta material is more valuable that other proposals and that it can be an advantage in the future.

Strengths of the Project Infoescuela with LEGO Dacta materials

According to the parents

1. **Interest in discovering, will to "assemble and disassemble everything".**

   The parents, as well as teachers emphasise that thanks to the program the children have a research attitude and the wish to constantly learn from the daily experiences. In this context, they say that their children learn from simple experiences and that they now are more motivated to go to school. Likewise, parents now notice that their children wish to contribute with ideas and creative solutions for the problems they face. Some relate that their children have become more observant, pay more attention and are willing to repair any mechanism damaged. Besides, the parents say that due to the program their children ask themselves more complex and elaborated questions. As a result, the children wish to find the solution through an active and constructive way instead of waiting for answers. They wish to discover *and solve by making.*

2. **More opened personality.**

   Now children talk more and work with more self-confidence in the different applicable and research activities related to the teaching of technological principles with the LEGO Dacta material. Furthermore some parent have said that their children have developed their self-esteem and strengthened their wish to work in groups.

3. **Motivation.**

   Parents say, that their children now look forward to the pedagogical teaching with the LEGO Dacta material.

Weaknesses of the Project Infoescuela with LEGO Dacta materials

According to the teachers

1. **Lack of material (biographic as well as sets and computers).**

   Teachers say they wish they had more computers and more time to familiarise with the materials. Likewise, they have said that the principals sometimes do not understand the purpose of the materials.

2. **Materials.**

   They say that sometimes the bibliographical material has been delayed. Likewise, the sets sometimes have not arrived at the arranged date.

3. **Training on Saturdays.**

   According to teachers this lessens their free time needed to rest or to be with their families. Likewise, they inform that the administrative and logistics aspects should be made within the working hours in order not to interrupt other activities programmed outside the school.

4. **They feel they lack knowledge about the science theory.**

   Teachers say they require more professional preparation to teach technology at school. They say that their knowledge is outdated and has little significance. They emphasised the need for specialised training in technology education. On the other side, they feel that there are no texts available in the national market, which can give them relevant information about the teaching of science and technology.

5. **The training received is irregular in quality.**

   Likewise there are many technical elements and a weak technical support.

6. **The teachers are afraid of the project not being continued and expanded**, stating that the receipt of the materials was so good, that it would be harmful to frustrate the children and the achievements they have made. They also meant stopping the program would be worse than not having had it at all.

7. **Some children monopolise the material and do not let the others work with it.**

   About this, teachers say that there should be a better training in the pedagogical and physiological handling of teamwork. This is due to the information they receive and is orientated to teaching in the traditional way. It was suggested that the LEGO Dacta training include everything about teaching strategies in groups.

8. **Weakness in the assessment.**

   To teachers the educational training and the materials do not have enough information about how to evaluate the skills and the material taught with LEGO Dacta material.

Weaknesses of the Project Infoescuela with LEGO Dacta materials

According to the students

1. According to the children working with the LEGO Dacta material encourage those who are leaders. In this context, the work is not always teamwork. Some "grab" the material to develop the project and dominate the rest with their own character.

2. Likewise, they say that the teachers do not know how to make the team work together, and that in many occasions there are children who only look how the others work.

According to the parents

1. **Some children grab all the material and do not let the others participate.**

   Like the students, parents also show their discontent about how the teachers inefficiently handle the meaning of teamwork.

2. **Lack of materials.**

   The amount of sets and parts is not enough for the great number of students. In this case, parent expressed that it would be important to assign more materials for each lab.

3. **Lack of communication among teacher/school and parents.**

   It appears that parents have not received much information from the school. Parents say that they are not well informed about the project and their scopes. They learn more about the project through their children.

Results of the durability study

CISE collected sample elements from the LEGO Dacta material used during 1998 by the EG schools. The durability and resistance of the elements were analysed in order to know the wearing of the product.

Operatively, the specialists of the institution compared the *sample elements* to *new elements.* Likewise, they assembled several models with both sample and new elements to check the Clutch Power. They also made lab analysis to know their weight and volume compare to the new ones.

Therefore, the results show that the LEGO Dacta material used intensively during one year do not show any wearing or modifications in their original design. Likewise, they found that the sample parts do not show any difference compared to the new ones regarding the assembling and dismantling of models.

We conclude that the LEGO Dacta materials have been elaborated with top materials and under extremely careful processes in order to have a material which lasts without wear.

Cost benefit

To find the cost-effectiveness of LEGO Dacta material starting from the information provided by the LEGO Dacta Representative in Peru, who says that the module of technological material costs $ 4 459 for each school, it is necessary to know the real number of students. For that, it must be taking into account that from the 7 schools studied, 5 has a morning an afternoon shift, while the other two have only one shift. Consequently, the number of students reaches 6 600 each year.

If we consider a minimum durability period – minimum 10 – the number of students would be 66 000 making US$ 0,47 per year the investment for each student.

Yearly Coverage

Total of School	Total shifts				Students	Coverage
7	School	Shifts/School	Sub-total	Total	Average/School	Total
	5	2	10	12	550	6600
	2	1	2			

Investment

Yearly Coverage	Cost/School	Global cost	Minimum Durability (years)	Students	Investment for student
					US$
6 600	4 459	31 213	10	66 000	0.47

Study of loss percentage and spare parts

In order to know the percentage of losses of the LEGO Dacta material the assessors of the Project Peace Education and Culture (CISE-PUC) made an inventory of all the LEGO Dacta parts used by the EG. In this case, they made an act with the Principal of the school, with a detailed list of the missing parts and loss percentage.

The analysis of the several reports shows that the percentage of loss of the LEGO Dacta material in the EG reaches 0.6%. If we consider that each school has received a resource set with over 1700 elements (set n° 9609) along with their material, we can estimate that thanks to the special care of the school, 15 years could pass without the school having to replace parts or needing a new set.

To this, we have to add the fact that the original set, even with a loss of 20% (and assuming that the resource parts have been used), allows an acceptable performance of the classes. As a result, it must be understood that its useful life expands even more than mentioned.

LEGO Dacta has a spare part service of individual parts, which would allow facing a loss of main parts like motors and axles, without having to buy a new set, but only the part itself.

Description of the LEGO Dacta concept

We believe that the hand is the leading edge of the mind and we are here to help children's minds, emotions and language grow. The LEGO Dacta products are the tools whereby we will bring this about and these tools will encourage creativity with the context of problem solving and exploration.

Any LEGO Dacta product is always part of an age appropriate developmental and educational progression.

How does it work?

The LEGO Dacta concept is based on the philosophy that the child should build his or her own knowledge in stead of the traditional educational system where the child passively listens to the teacher and sees, take notes, writes and repeats.

In a classroom with 30-40 students there is only a very limited amount of time per student, which means that only a few will be able to express themselves verbally during a lesson. Shy students will try to 'hide' and the strong children will do the talking.

With the LEGO Dacta concept the child has to be active and part of a group. These individual groups of 2-4 children are designing and building with LEGO Dacta materials.

By introducing teamwork and problem solving activities the children in the groups have to communicate with each other. Shy children fell more secure when talking in a small group in stead of in front of the whole class. In order to solve the problems the children have to co-operate. They have to observe, think, explore, investigate, innovate and be creative. It might be that the shy child is very creative, and by being one of the best in his group his self-esteem will be improved.

The LEGO bricks are all made with studs. This means that during the construction phase the children are counting and calculating all the time, but without noticing. This gives room for improvement of basic math skills.

The problem solving activities are a challenge to the children. Each group wants to develop the best solution to the problem. This stimulates the concentration and changes the attitude of the children.

They wish to find the solution in an active and constructive way instead of waiting for answers.

The structure of the LEGO Dacta materials

The LEGO Dacta products have the following characteristics:

- Versatility and Progression
- Brain/hand interaction
- Motivate both children and teacher
- Curriculum relevant
- Safety and quality

Each LEGO Dacta product is structured in the same way:

- A Teacher's Guide with relevant background information on the topic. The Teacher's Guide is divided into modules with suggestions on how to structure the lessons. The objective is to have a short preparation time and allow teachers with no technological knowledge to feel safe about using the material in the classroom.

- Activity cards/copy masters for the students, which are linked to the modules in the Teacher's Guide. Each activity card corresponds to one lesson.

- The LEGO Dacta building set contains LEGO bricks/elements and building instructions.

There are three phases when teaching with the LEGO Dacta material:

Exploration - introduction to a new subject. The teacher explains the concept of e.g. gears and the students are building simple models using gears. This phase is a combination of theory and hands on learning, where the students are "constructing" their knowledge.

Investigation - the link to the real word. The students are building and operating small-scale models simulating real life machinery in order to put the concept of e.g. gears into a context. This phase is Real life simulation in pocket size, where the students will practise their knowledge.

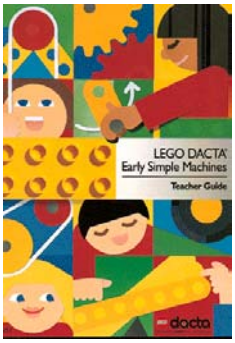
Problem solving - the open-ended phase of combining knowledge, skills and creativity. The students are designing practical solutions to real life problems. This is the phase where the students will challenge their knowledge and become problem solving oriented.

Educational materials for 1st and 2nd grade of the INFOESCUELA Project

LEGO DACTA Early Simple Machines I/II (9651/9654)

The Early Simple Machines set is designed for age group 5-8 years and is based on DUPLO elements. DUPLO bricks are very large LEGO bricks. Apart from the standard DUPLO elements the set contains specially designed elements like gears, pulleys, axles, wheels, belts, beams and handles. These elements are only available from LEGO Dacta.

The elements fulfil all safety requirements for the age group. There are no small elements that can be swallowed, no sharp edges, and the strings included are within the maximum length to prevent strangulation.



The students will have their first experience with simple mechanisms like gears, pulleys, levers and wheels and axles.

It only takes a few elements to build the fun models simulating the real world that come with easy to follow building instructions. The children will stimulate their gross and fine motor skills. At this stage the children will get a sense of the mechanical principles, they will not be calculating gear ratios etc.

For the teacher there is a very short preparation time and no technology experience is required. Early Simple Machines is quick to organise and use, it gives answers to many technical questions and is an instant success with the children.

When teaching with the set, there are three phases: exploration, investigation and problem solving. The teacher's guide gives thorough explanations to the activity cards/copy masters including purpose, key ideas, activity ideas, questions and answers, possible solutions and extension ideas.

The Early Simple Machines set is widely used in a cross-curricular context. An example: The topic wheels and axles include building a car. This car can be linked with themes like the history of transportation, energy, pollution, and infrastructure. The hands on experience keep the interest of the children and the car and transportation become something they can relate to in practise not only in theory.

9651 Early Simple Machines I was launched in January 1996 and 9654 Early Simple Machines II was launched in January 1998. A part from the same activities as 9651, the 9654 set holds several extra activities based on new elements like the crown gear and the worm gear, which is used in a special gearbox.

Educational materials for 3rd and 4th grade of the INFOESCUELA Project

LEGO DACTA Simple & Powered Mechanisms 9630/2009645 an LEGO Control Centre 9752

The Simple & Powered Mechanisms set is designed for the age group 8-14 years. It is based on LEGO Technic elements. The LEGO Control Centre has three 9-volt outputs for the children to motorise their models. It is powered either by batteries or by a 110/220-volt transformer. The LEGO Control Centre was chosen to avoid the use of batteries in the classroom.

Many of the LEGO Technic elements like the gears; pulleys, bushings and handles are fairly small but developmentally appropriate for the age group. To maintain the interest and avoid boredom the children have to work with material that progressively becomes more complex.

The students will get a thorough introduction to structures and forces, levers, gears, pulleys and wheels and axles. The models can be manually operated or powered by the 9-volt motor and the new easy to understand gearbox with worm gear shown on the photo.

The more than 75 models that come with building instructions do all have a direct link to the real world. The models are a lot more complex to build than the DUPLO models from Early Simple Machines and they will sharpen the students' ability to concentrate and observe. At this stage the students will also whilst working with the mechanical principles be counting rounds per minute and calculating gear ratios.

There are three phases when teaching with the Simple & Powered Mechanisms:

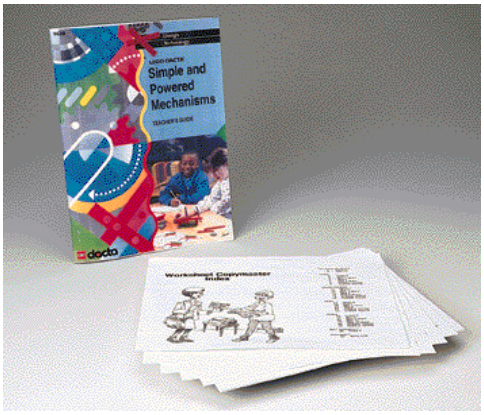
The exploration phase is where the students are getting to know e.g. gear principles, like gearing up, gearing down, change of direction and compound gears. Each set holds 8 building instructions for exploring basic mechanisms and the teacher holds a set of activity cards/copy masters with questions and challenges.

The investigation phase is where the students use a basic mechanism in a context. There are two investigations for each basic mechanism. Each of the two mechanisms can be manually operated or motorised. Activity cards support these investigations as well.

The problem-solving phase is where the students use their newly acquired knowledge together with skills and creativity to solve real world problems related to the basic mechanisms. There are two problem-solving activities for each basic mechanism.

The Teacher's Guide is divided into modules that give a clear overview on how to prepare the lessons. There are thorough explanations to the mechanical principles and the structure of the material results in a short preparation time. The 31 activity cards/copy masters are reproduced in the Teacher's Guide with all the answers to the questions filled in.

The many links to the real world makes the set excellent for cross-curricular applications.



Educational materials for 5th and 6th grade of the INFOESCUELA Project

LEGO DACTA Control Lab

Control Lab is designed for the age group 10-16 years. The set is intended to develop the students' information technology capability on a learning-by-doing basis. The Control Lab building set is based on LEGO Technic elements and introduces sensors, light and sound. The LEGO DCAT interface B that connects to a PC or a MAC has 8 outputs for motors, lamps and sound elements and 8 inputs for temperature, light, angle, rotation and touch sensors.

The Control Lab software, which is translated into Spanish, is based on the LEGO TC Logo programming language, which was developed by Dr. Seymour Papert.

The students learn to use the computer as an interactive tool to program and control LEGO models. They use sensors for measuring and to visualise these measurements by making graphs on the graphs and other read outs on the computer.

The literature package for the teacher is divided into two parts:

A Quick Start teacher's guide with 12 quick start cards/copy masters for the students. The teacher's guide give an overview of the Control Lab package and give hints to classroom management and a thorough explanation on how to use the quick start cards. The quick start is a step by step introduction to programming, controlling and using the sensors for measuring. It includes the building of a fan model with a temperature that in a very simple way let the students understand how an air condition system works.

A Project teacher's guide with 7 project cards/copy masters for the students. The teacher's guide give ideas on how to set up the projects and also possible solutions to each of the 7 projects. The projects comprises among others a robot arm, a conveyor belt with light sensor for sorting coloured bricks, a joystick controlled wheel chair, a scanner, a car testing station and a temperature controlled green house.

Control Lab is ideal for project weeks and cross-curricular applications. A good example is the temperature controlled green house, which can be used themes like the vegetation's need for sun and rain, agricultural development and the effect of global temperature changes.

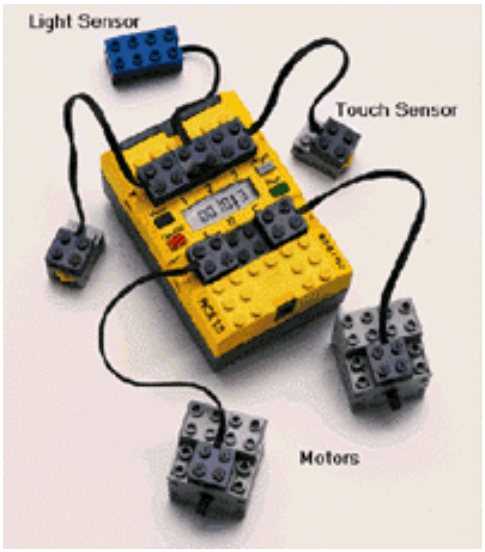
Control Lab is very flexible as it can be used for simple controls and measurements and for very advanced and complex projects depending on the time available.

Future materials for 5th and 6th grade

RoboLab – LEGO MindStorms for schools

In the coming expansion of the INFOESCUELA Project the new RoboLab will replace the Control Lab used in 5th and 6th grade. RoboLab is based on the new revolutionary programmable brick, the RCX.

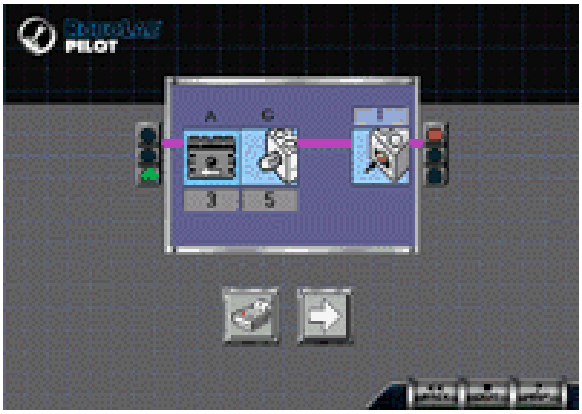
The advantage of the RCX is that programs are downloaded into the RCX via an infrared transmitter. As the individual RCX is not physically connected to the computer up to four groups of students can use the same computer for programming their four RCXs.



The RoboLab Software is an icon software using LabView from National Instruments as platform. It is available for both PC and MAC.

There are 8 programming levels. 4 pilot levels and 4 inventor levels. The students can progress, as they become familiar with each level.

Because of the built-in progression students from 8 years of age up to university level can use the software.



The RoboLab set used for 5th and 6th grade is called the RoboLab Starter System. It is a set comprises four different models each with five modification possibilities. The four models can be built at the same time. This way four groups in the classroom can work with only one RoboLab Starter System.

The RoboLab Starter System contains over 1600 elements, which gives room for creativity in the problem solving phases.

The 274 pages teacher's guide/activity pack covers classroom management, whole class activities, and assessment ideas, works sheets and a thorough introduction to robotics.

The four models in the RoboLab Starter System are:

- My home – The intelligent house, where the students control the light, the television and CD player by means of sensors, even an automatic bed that throws you out at the first daylight. Learn to run the perfect electronic household.

- The Gadget – A device that works with lamps, touch sensors and light sensors. Build your own intelligent burglar alarm. Test your speed of reaction by activating the sensors with a real multitasking program.

- The Car – An intelligent vehicle. Activate the touch sensor and the car will stop, start, reverse or flash the light.

- The Bug – Understand the way insects are moving and put a range of behavioural patterns into this touch sensor controlled bug.

A fifth model is the table edge finder, which requires co-operation, creativity and good programming skills by the students.

Understanding the Peruvian Results

The results of the Infoescuela project indicate an increase in the test scores of students using the LEGO Dacta materials as compared to a control group. How do we understand these positive results? What is it about the materials and the way they were used that enabled students, seemingly, to learn more?

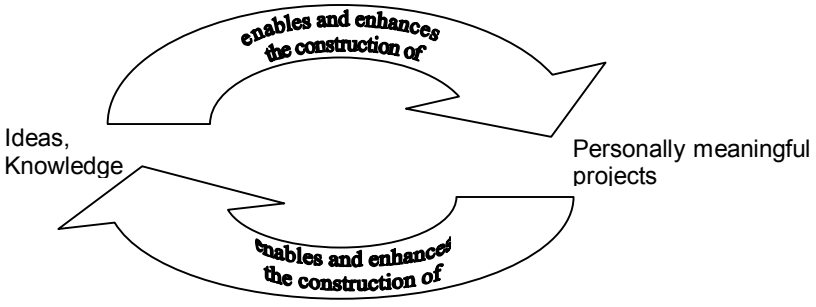
The Theory: Constructionism

The LEGO Dacta materials were designed according to a theory of education called "constructionism". This theory, developed by Professor Seymour Papert and his colleagues at MIT, can be stated as follows:

- Learning happens especially well when children are engaged in constructing a meaningful product, such as a sand castle, a poem, a machine, a story, a piece of artwork, a computer program, or a song.

- When children are involved in creating something, making something, building something, they are simultaneously building knowledge in their minds. They are trying out ideas, making conjectures and testing them, making connections between ideas or reorganising them - in short, they are building knowledge structures.

- This newly formed knowledge enables children to build even more sophisticated constructions, which yield still more knowledge… and so on, in a self-reinforcing cycle.



Why It's Better

Too often, conventional instruction methods emphasise the memorisation of facts and information. Students are tested to see if they can reproduce this material on demand, to see if any of it is "retained". Students who are good at memorisation can often score well on such tests, but many of them forget the material as soon as the exam is over. This activity cannot truly be called learning.

Rarely, if ever, do students get a chance to use what they are taught. At best they are told that all of this material will be useful to them "sometime in the future" or "when they grow up." But in fact it bears little or no relation to their present lives and concerns.

Problem sets in math and science textbooks do attempt to get students to use the subject matter presented, but such problems are geared toward getting the students to produce a specific, wanted "right" answer. They are not open-ended problems. They do not usually involve making or constructing anything. They do not engage the student's fantasy, creativity, and imagination. That's why students frequently find such exercises BORING. And what's boring is not typically learned well or remembered.

Even though the Control Group in the Infoescuela project study had access to various sorts of scientific equipment (scales, magnifying glasses, magnets, test tubes, clocks, graduated cylinders, etc.), these materials were not used to construct anything of interest to the students. Rather they were used in cookbook-like exercises that were meant to demonstrate various scientific principles. While this approach may be an improvement over mere memorisation, it does not come close to conveying what doing science is actually like.

This is where the LEGO Dacta materials are different. Students using these materials are presented with some very basic theoretical explanations of, say, how a lever works. Then, as soon as possible, students get to use this knowledge to construct an actual lever out of LEGO elements. They get a chance to use this lever, to play with it, to conduct some experiments and investigations with it, and to solve some simple problems. In this way, students get hands-on experience with using levers (or gear chains, or wheel-and-axle assemblies, or pulleys, or other such devices) they themselves have constructed. But that is not all. Students are then asked to mobilise this new knowledge to solve several open-ended problems (or "challenges" as they are called) - problems that do not have one "right" answer. This is where students get to flex their creative muscles. This is where we see real excitement and engagement on the part of the students. And it is just this engagement and emotional investment in the task at hand that makes it much more likely that students will not soon forget what they are learning. This, in the end, is why the overall test results for the LEGO Dacta students came out higher than the control group: their learning was personally meaningful, exciting, engaging, involved producing tangible products, and tapped into their creative imaginations. (The children would probably just say, "It was hard, but it was fun!")

For older, more advanced students, the open-ended problems or "challenges" can be quite complex and sophisticated, involving computer programming and control in conjunction with LEGO model building. For example: Build a "vending machine" that will dispense different colour LEGO bricks at the touch of a button, after a "coin" has been inserted into a slot. Or, build a model of a greenhouse with a ventilation panel that will open or shut when the maximum or minimum temperatures are reached. (This latter project has obvious real-world applications, which carries with it extra motivation). Mere memorisation of facts and formulas is insufficient for solving these sorts of problems. What is called for is true understanding. But achieving a workable model (in the example cited, a functioning vending machine) is only one part of the exercise. Equally important, if not more important, is the process involved, that is, the way in which students go about solving such challenges. All the false starts, the hunches pursued and abandoned, the wild ideas that may not work in the end (though sometimes they do!), the trial and error, the discussion and negotiation that goes on among students, the books consulted - all these things are what doing science is actually about. Far from being mistakes or evidence of students "floundering," these experiences contribute greatly to the development of the students' thinking skills and creative problem-solving abilities. As the educational critic John Holt observed, "The true test of intelligence is not how much we know how to do, but how we behave when we don't know what to do."

In sum, students who use the LEGO Dacta materials in these ways learn more, and more deeply, because their activities come much closer to what scientists and engineers do, as contrasted with conventional lessons on which students are taught about science and technology. In the Infoescuela project, students got to be scientists, engineers, and designers. The importance of this difference cannot be overstressed.

Still Room For Improvement

The positive results of the Infoescuela project give weight to the power of constructionist theory and of the LEGO Dacta educational materials. But there is still room for improvement. The Infoescuela project has only begun to explore the limits of how far these educational ideas can be taken.

More attention needs to be paid to what Professor Papert has termed "the learning culture," meaning, the social and cultural aspects of the classroom situation. A greater diversity of skill level can only enhance the quality of learning in that culture. This may mean combining students of different ages and skill levels in a given classroom setting. When students are all at the same level, they sometimes reach a plateau and are at a loss for ideas and directions in which to advance their work. In a more diverse setting, students with less experience can learn much from freely associating with others who display a skill level slightly above their own. Students with more experience refine their skill and knowledge through helping and explaining things to others. And the diversity of artefacts created by students at different skill levels fuels everyone's creative imaginations. Ideas are borrowed and embellished throughout the learning culture in an exciting, vibrant cross-fertilisation of knowledge.

In the absence of this diversity of skill, too much responsibility is placed on the teacher to act as the fount of knowledge and ideas for the entire classroom. This is often too much for an individual teacher to bear, even after receiving the best of training. (The teachers involved in the Infoescuela project at times complained that the technical training they received was insufficient or inadequate.) In a more diverse learning culture, the teacher is less a fount of knowledge and technical information and more like the principal investigator of a real scientific research team. In real life, the principal investigator does not have or know all the answers. But such a person has a knack for asking the right question at the right time, has a keen sensitivity for group dynamics, and possesses a good overall view of the research community in terms of knowing who the various experts are in given areas. This is how real science works. It should work no differently in a constructions learning culture.

Similarly, in a real-world scientific research team, different players have different roles. Some people perform the experiments, others take notes and write up the results, and still others consult journals and reference books for ways to overcome setbacks and obstacles. Rarely do all members of a team do "exactly the same thing." At the same time, these roles are not rigid either. A given individual may slip from one role into another, as the work demands. It would seem important for students in such an enterprise to try on different roles (the builder, the programmer, the note-keeper, the researcher, and so on) to see which roles appeal to them and which don't.

Additionally, a much greater degree of choice could be built into the LEGO Dacta materials than the accompanying "activity cards" typically allow. The greater the choice a student has of what to construct or create the greater the likelihood of personal engagement and investment in the task. The particular projects described in the activity cards are by no means bad, but their range may be too limited to appeal to the tastes and interests of the greatest number of students. Rigid adherence to the prescribed activity cards, even the open-ended project cards, may be ultimately self-limiting. Teachers should by no means feel limited by the projects described on the activity cards. In the spirit of "brainstorming," new project ideas should be generated by the group. Furthermore, if there are enough LEGO materials on hand, old projects should not be disassembled but should be kept around for students to inspect and emulate.

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