



THE COGNITIVE ACCELERATION CURRICULUM AS A TOOL FOR OVERCOMING DIFFICULTIES IN THE IMPLEMENTATION OF INQUIRY SKILLS IN SCIENCE EDUCATION AMONG PRIMARY SCHOOL STUDENTS

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Introduction

Theoretical Background

Scientific inquiry tasks combine experimentation with mental and practical skills that characterize the strategy of scientific thinking. Experimentation in the inquiry approach involves both a process aspect, focusing mainly on the planning of experiments, observations and data collection, and also an intellectual aspect, consisting mainly of interpretation and explanation, which eventually give rise to new insights. In an experiment one interferes deliberately and in a structured way with some natural phenomenon in order to test a hypothesis, law or theory. Experimentation combines isolation of variables and control (Dvir, 2000).

Both students and teachers report numerous difficulties and frustrations in their attempts to implement the inquiry approach, so much so that the learning process may fail (Zohar, 2006). Students find it difficult to apply appropriate inquiry skills at every stage of the inquiry process, including definition of the problem, planning the experiment, carrying out the experiment, analysis of the results and drawing conclusions (Keselman, 2003).

Difficulties that may attend a scientific inquiry include control over the thought schema as well as variable control and supervision. The foundation of such a schema is the understanding that a well-planned experiment should be based on changing a single variable at a time, keeping other variables constant, in order to clearly identify the connection between cause and effect (Zohar, 2006). This, in turn, depends on the ability to identify the relevant variables in the given problem and to remove irrelevant ones (that is, to distinguish between what is significant and what is not), while keeping

Abstract. *Many primary school pupils find it difficult to apply inquiry skills in general and variable control in particular, and fail to appreciate the importance of control groups in scientific research. The present study focused on levels of thinking among sixth-graders in the course of an open-ended inquiry activity, by following the planning and execution of an experiment, isolation and variable control, and the difficulties encountered by students in the implementation of various inquiry skills. The study population consisted of forty-four sixth-graders from a primary school in the Arab sector in Israel's Northern District. The students were divided into two groups, one that underwent a process of intervention in teaching in the form of three lessons using the CASE approach, while the other learned with the New Outlook textbook. The study's results point to a significant difference between the CASE intervention group and the New Outlook intervention group with respect to the final grade of the "variable identification and connection test". An examination of the differences in student achievement between the pre- and post-test reveals an improvement in the post-test final scores among the CASE group of students, in comparison to the New Outlook group.*

Key words: CASE, cognitive acceleration, curriculum, inquiry skills, science education.

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open the possibility of manipulating various combinations of variables (Zohar, 2006). The ability to make proper use of such a schema is thus of prime importance in scientific inquiry, both at the planning stage and when interpreting the results (Babai & Levit-Dori, 2009).

According to Schauble (1996), and Bullock and Ziegler (1999) the research that focused on controlling the reasoning schema, isolation and control of variables and the ability of primary-school students to control scientific inquiry skills in order to plan complex experiments and reach conclusions based on the results is poor.

Shayer & Wylam (in Shayer & Adey, 1994) describe a study conducted on fifteen-year-old students who were presented with a system consisting of a short pendulum and a heavy weight. The students were asked to answer the following question: "What arrangements would you make in order to test the effect of pendulum length on the swing rate?" Only about thirty percent of the students answered correctly, using the principle of variable isolation and control. Most of the students changed more than one variable and, having changed two variables, ascribed the effect to both.

Another study (Zohar, 2006) reported reasoning problems among ninth-graders in the course of an open inquiry activity, in the experiment planning and implementation stages. The characteristic shared by most students was a lack of variable isolation and control.

A similar study on twelfth-graders specializing in natural science who also took a separate study unit in inquiry skills, showed that the main difficulty which they experienced concerned the planning of a battery of experiments, especially how to explain planning and variable control and isolation (Ratner, 1995).

Research by Iqbal and Shayer (2000), and Endler and Bond (2001) suggest that the development of cognitive abilities among students often does not match the cognitive demands made on them by the science curriculum. Recently a variety of studies were conducted at Tel-Aviv University in Israel, that showed that fewer than twenty-five percent of eighth- and ninth-graders reach the level of formal reasoning; the overwhelming majority of the study populations were at the pre-formal stage (Habib Allah, 2007; Levitt-Dori, 2006; Mendelsohn, 2008; Fingerhut, 2006). The findings point to difficulties in controlling the variable isolation and control schema. Since this schema is associated with formal operations, it is to be expected that students who are at a lower level of cognitive development will encounter greater difficulties in implementing inquiry learning (Shayer & Adey, 1994). These studies bring to light yet another difficulty in the implementation of the curriculum among primary school students, namely implementing inquiry learning and controlling the variable isolation and control schema.

The Cognitive Acceleration through Science Education (CASE) intervention program in teaching (Adey, 1999) was developed in order to increase the pace of cognitive development and improve learning abilities and academic achievement. The program is based on practical studies involving cognitive conflicts whose resolution requires the use of Piaget's formal reasoning schema, and on cognitive studies that analyze the way children at different ages learn (Adey, Shayer, & Yates, 2001). The CASE intervention program fits the constructivist approach for science education, because the way in which it is implemented makes significant active learning possible. Piaget (1975) argues that in order to cope with the difficulties of applying inquiry learning one should study how cognitive thinking develops in students, since his own research on children's cognitive development described scientific inquiry as a characteristic of formal thought processes. Furthermore, intelligence undergoes a natural evolution at certain fixed stages, whose order is constant among all children. Each child moves from one stage to the next in a gradual manner and in constant interaction with the environment. The age at which children reach each of these stages is not constant and depends on genetic and environmental factors. Piaget explains that a student requires a level of formal reasoning in order to succeed in scientific research (Piaget, 1975). Moreover, Vygotsky argues that there is a cognitive gap between what a student is able to do on his/her own and what he/she is capable of doing with the help of an adult (Vygotsky, 1978). The teacher's task is therefore to create interactions among the students, to ask questions that promote interactions in groups and to create mental stimuli by arousing cognitive conflicts. However, an even more significant factor in learning is the learner's interaction with his/her peers (Shayer, 2003).

In the NEW OUTLOOK teaching model, the science are taught in a traditional approach, in other words the teacher acts as a transmitter of the scientific knowledge to the students, but does not create opportunities for plenary discussions and for listening to the students. The CASE teaching model on the other hand, requires a shift from the teacher, as a transmitter of information, but rather that of a coordinator possessing classroom management and guidance skills. The teacher must be able to listen and also to combine teaching in groups with plenary discussions. Studies at the Tel-Aviv University's School of Education described successful cases of using a number of lessons from the CASE program to enhance probabilistic reasoning and variable isolation and control schemas (Habib Allah, 2007; Levitt-Dori, 2006).



The CASE method possesses elements that make it appropriate for teaching science via a socio-cultural approach (Lunetta, 1998). According to this approach information has meaning only within the community that uses it. In the case of the sciences, the relevant community consists of the scientists who are working on the research that is taking place in the lab. Therefore learning also has to take place in the lab, where the same actions have to be carried out as those which the scientists perform. When they do research, scientists ask questions, formulate hypotheses, discuss and formulate explanations. The students who participate in learning via the CASE approach also perform all these actions. Therefore this is an appropriate environment for the learning of science, according to this approach.

Research Aim and Research Questions

The aim of the study was to discover whether it would be possible to bridge the gap between sixth graders' cognitive level and the reasoning ability they are required to show when implementing the variable isolation and control schema using the CASE program, in comparison to the outcome using the traditional NEW OUTLOOK program.

Hence, our research questions were as follows:

1. How do students perceive the term "control group" in scientific inquiry?
2. Does learning variable isolation and control using the CASE program improve sixth graders' scientific and technological thinking, compared to traditional teaching using the NEW OUTLOOK program?
3. How do students learn to distinguish between dependent and independent variables in scientific inquiry?

Methodology of Research

General Background of the Research

The students of the CASE group were required to carry out the following three experiments, whereas the students of the NEW OUTLOOK group learned science without performing these three experiments, i.e. they learned sciences theoretically without experimentation.

The three experiments of the CASE group were:

1. *The effect of light on the amount of chlorophyll in leaves*

The influencing factor (independent variable): Light intensity

The affected factor (dependent variable): Amount of chlorophyll in leaves

Experiment: the plant leaves were exposed to light at different intensities, at each of which the amount of chlorophyll in the leaves was measured;

Observation: the amount of chlorophyll in lemon leaves exposed to sunlight was compared to that in lemon leaves covered with aluminum foil. The amount of chlorophyll in lemon leaves exposed to sunlight was measured.

2. *Rising dough*

The influencing factor (independent variable): Yeast

The affected factor (dependent variable): Volume of the dough

Observation: the volume of the dough with yeast was compared with that of the dough without yeast. Hypotheses were made concerning the factors that contributed to raising the dough.

3. *Redi's experiment*

In the year 1668 an Italian physician by the name of Francesco Redi placed a number of jars containing spoiled meat on the windowsill in his home. Some of the jars were completely sealed, some were covered with gauze and the rest were left open. Thus began what is widely considered to have been the first-ever scientifically valid experiment in biology (Ioli, Petithory & Théodoridès, 1997).

The one feature of this experiment that made it unique and gave it the title of "the first experiment in biology" was its use, perhaps for the first time in the history of science, of the concept of a control experiment. Redi did not only show that there were no flies in the closed jars, but also demonstrated that under exactly the same conditions, except for the one condition for which he tested, namely the access of flies to the meat, flies did appear. The control experiment has ever since been one of the most important principles in the life sciences. This and subsequent



experiments succeeded in completely refuting the theory of spontaneous creation of life; there was now enough compelling evidence that living beings were only created by other living beings.

Three lessons in the life sciences whose purpose was to accelerate the acquisition of the variable isolation and control reasoning schema were given to the students of the CASE group. Table 1 summarizes these three lessons. Each lesson was carried out using the CASE method (Aday et al., 2001): Concrete preparation, cognitive conflict, constructivism, mediation and meta-cognition. In the NEW OUTLOOK program the students learned sciences without experimentation; in other words, they did not perform any of these three experiments.

Table 1. The lessons given to the CASE intervention group on the variable isolation and control schema.

Lesson	Lesson subject: the important terms taught in the lesson	Comments
1: What is a variable?	Initial lesson in which the terms "variable" and the "value" of a variable are taught. Preliminary acquaintance with possible connections between variables. This lesson does not include any experimental work	Classroom activity consists mainly of concrete preparations. Time: About forty-five minutes
2: Two variables	The students carry out three brief experiments and do an activity sheet in which they modify one variable and check what happens to the other (for example, the volume of the dough). The students become acquainted with scientific terminology: Influencing factor (the variable which they change in the course of the experiment – the independent variable) and affected factor (the experiment's results – the dependent variable)	The students perform all three experiments, one after the other. This lesson and the previous one take place on the same day. The activity was carried out in small groups of four to six students each. The teacher was instructed to pose questions that promoted meta-cognition. At the end of the lesson a bridging process took place to connect what the students did to previous experiments that they had performed.
3: Connections between variables	The lesson consisted of two short activities after which the students were asked to draw graphs as representative pictures of the relationships among the variables encountered in the activities. Stress was laid on reading graphic information rather than on graphing skills	First activity: Measuring the volume of the dough relative to the amount of yeast. One test tube is left with only dough and no yeast (control group). After the concrete stage of the experiment comes the meta-cognitive stage, consisting of a discussion of the graphs that have been produced and the ability to predict outcomes. Time: Two hours.

Research Population and Research Sample

The research population consisted of sixth grade Arab students (age 12 years) whose parents agreed to having their children participate in this research. The research sample consisted of forty-four sixth-grade students from two classes in a primary school belonging to the Arab sector in Israel's Northern District who learn in their first language (Arabic). One class of twenty-two students (the cognitive acceleration group) learned using the CASE method, while the other class, also with twenty-two students, learned in the traditional method, using only textbooks and without intensive experimentation. The two selected classes had similar grade averages, according to the achievement mapping grades in the second half of the school year.

The Research Instrument

After the teaching-learning process for the two groups, the CASE group and the NEW OUTLOOK group, came to an end, the students were given a questionnaire containing four activities that tested the effect of the independent on the dependent variable, and students' ability to identify the two variables as well as the control group (Appendices 1-4).

Data Analysis

In order to determine whether there are differences in students' ability to plan an experiment for variable isolation and control in scientific inquiry, a t-test (1.86) was conducted on an independent sample, in order to compare the achievements in the questionnaire of students in the CASE intervention group with those of the NEW OUTLOOK intervention group.



Results of Research

For the first research question, *how do students perceive the term "control group" in scientific inquiry?* In both groups the students clearly found it difficult to understand the importance of the control group. In the questionnaire on the third and the fourth task, the students were asked to explain the importance of the control group for the experiment. The CASE intervention group received a mean grade of 2.09 with a standard deviation of 0.86, while the NEW OUTLOOK group had a mean grade of 1.27 with a standard deviation of 0.827 (out of 3); 3 points were given for a correct answer. The students were given a qualitative questionnaire which was converted for quantitative presentation as follows:

- a) A. A student whose answer involved more than a single factor received one point;
- b) B. A student who gave a partial answer and involved two factors received two points;
- c) C. A student who gave a complete answer involving multiple factors and provided a correct explanation received three points.

In order to answer the second research question, *does learning variable isolation and control using the CASE method improve sixth graders' scientific and technological thinking, compared to traditional teaching methods?*, the academic achievements of the CASE intervention group were compared to those of the NEW OUTLOOK intervention group. The comparison was made using the final grade of the concluding questionnaire and the variable identification and relation test.

In order to answer the third research question, *how do students learn to distinguish between dependent and independent variables in scientific inquiry?* The students were asked, as their first task, to distinguish between the dependent and independent variables. In the CASE intervention group many of the students succeeded in answering the questions posed in the experiments and received three points (as explained above). Their average grade was 2.45, with a standard deviation of 0.67. These students were instructed by the teacher and received guidance when doing the experiments. The students of the NEW OUTLOOK group, on the other hand, had an average of 1.59 with a standard deviation of 0.959. The difference between the two groups shows that when the teacher does not intervene in teaching scientific inquiry, students seem to find it difficult to distinguish between dependent and independent variables. Thus, in the dough raising experiment many of the students were unable to answer the question, *what caused the dough to rise?* The above occurred as the students were unable to isolate the variables.

The students' grades in the school mapping test, a test that is conducted by the ministry of education for the whole primary school students that aim to measure the student's achievement in the science discipline, did not reveal any significant difference in their initial state. It is worthwhile to say that the students of both groups; i.e. CASE and NEW OUTLOOK groups, were learned science discipline similarly before they participated in this study. Hence, before the intervention (see Table 2) the average grade of the CASE cognitive acceleration group was 66.5 (SD=13.6) and that of the NEW OUTLOOK intervention group was 74.3 (SD=14). In a t-test statistical comparison on independent samples, the differences between the two groups were not significantly different ($t=1.86$, $p>0.05$) before the intervention, based on the school mapping for the sciences. In all three experiments (Table 1) the students of both groups (CASE and NEW OUTLOOK) received an explanation about dependent and independent variables.

The questionnaire consisted of a collection of questions dealing with variable isolation and control skills in scientific inquiry. Its purpose was to test students' command of the variable isolation and control reasoning schema, identification of the research hypothesis, relations between variables, separation of variables, and planning a simple experiment.

Table 2. Comparison of the grades of the CASE intervention group with those of the NEW OUTLOOK group. (n= 22 for each group).

Test	Variable	Group	M	SD	Df	t-test	p
Before intervention	Achievement mapping test grade	CASE Group	66.55	13.66	42	1.86	0.07
		NEW OUTLOOK Group	74.32	14.05			



Test	Variable	Group	M	SD	Df	t-test	p
After intervention	Final exam grade	CASE Group	72.42	9.07	42	5.8	0.001
		NEW OUTLOOK Group	53.79	12.03			

The results of the t-test (Table 2) show a significant difference between the CASE intervention group and the NEW OUTLOOK intervention group, in the final grades of the “variable identification and relation test”. This result may be taken as confirmation of the research hypothesis that a significant difference will be found in the average achievements of the two groups, CASE and NEW OUTLOOK, in the final test and in the variable identification and relation test.

The differences in student achievements between the pre- and post-test as measured by the t-test (see the table above) show that the CASE group improved more than the NEW OUTLOOK group.

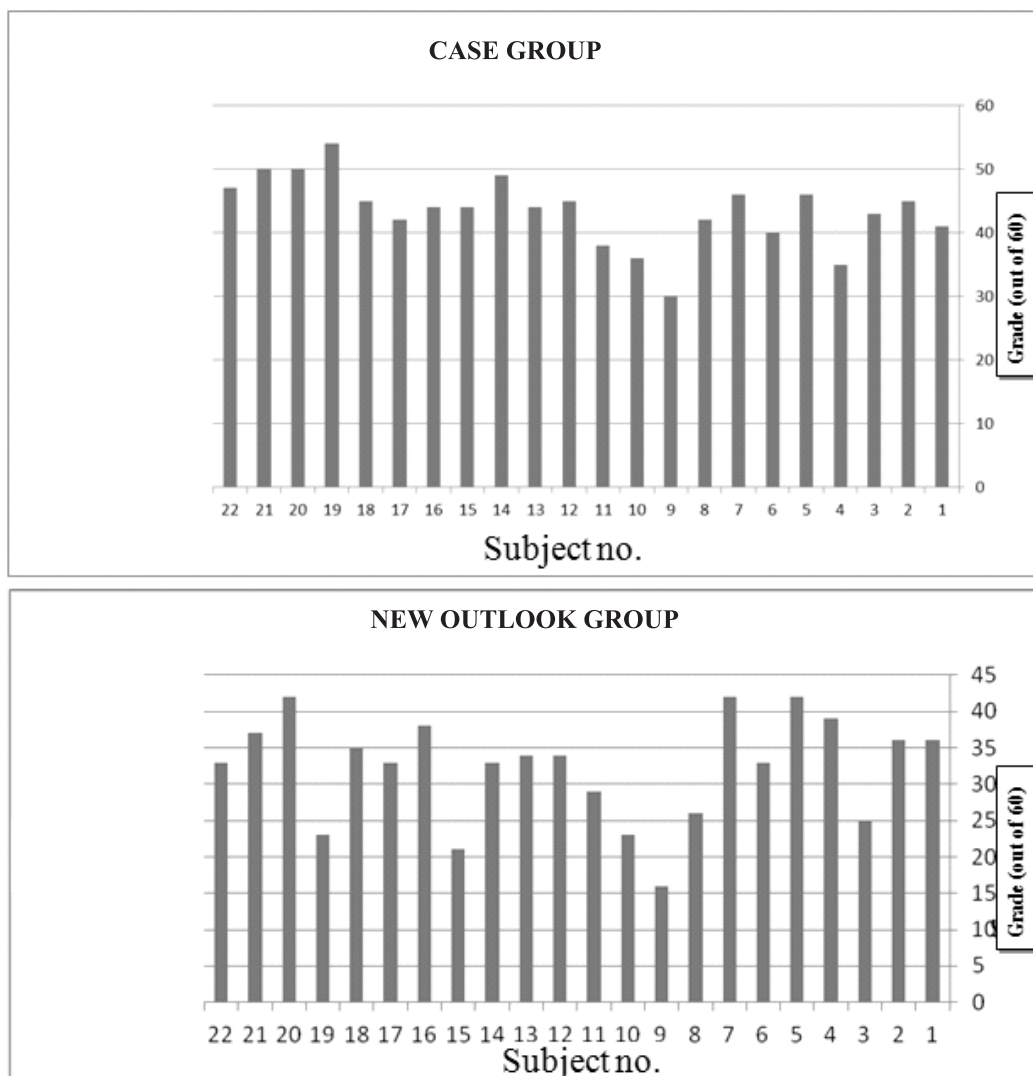


Figure 1: The grades of the CASE group and the NEW OUTLOOK group.

(Note: the grade (60 points overall) consists from the following: Task A, 14 items, three points per item; task B, two items, three points per item; task C, two items, three points per item; task D, two items, three points per item.)



Discussion

It is very likely that the main factor contributing to the success of the CASE group was the teaching intervention process. The advantage of this teaching method is that it accelerates the development of the afore-mentioned cognitive schema and so improves students' ability to solve problems associated with inquiry skills. According to Piaget (1975), sixth-grade students (ages eleven and twelve) have yet to attain abstract cognitive maturity, and therefore the teacher has an important role in guiding students to an understanding of the distinction between concrete and abstract. The aim of the CASE intervention program is indeed to impart scientific methodology and develop students' scientific reasoning. The program apparently did in fact provide the learners with the skills and abilities they needed for cognitive acceleration and improving their final grade.

The results of the present study (see fig. 1) would seem to indicate that using a syllabus that focuses on learning inquiry skills can improve learners' ability to use the variable isolation and control reasoning schema in tasks that require the application of this schema. Other studies on the subject of variable isolation and control in various contexts demonstrated that a combination of exercise, training or intervention in the learning process with a focus on variable isolation and control skills can improve students' ability to cope with problem solution tasks that require such skills more than the control group. It may be assumed that the main factor contributing to success in these studies was the process of intervention in teaching (Rubin, 1990; Lawson & Wollman, 2003).

In the present study it was found that students who learned according to the CASE method had more success than students who learned by the NEW OUTLOOK textbook. This can be ascribed to the unique hierarchically structured lesson sequence on variable isolation and control used in the CASE program: First students are made acquainted with the concept of "variable" and the difference between variables and their values; then they are taught to understand the terms "dependent variable" and "independent variable"; at the next stage they learn about possible connections among variables and how they are represented graphically; finally, they are introduced to the concept of controlling variables that are not relevant to the problem and made to understand the idea of a "fair test", in which one changes only one variable in each experiment while keeping the others constant. The answers which the students in the CASE group gave to the questions in the four tasks show that although they improved considerably in comparison to the other group, they still had difficulty in answering questions that require high-order thinking, involving understanding, generalization of results, derivations of conclusions, and analysis. According to Piaget's developmental theory (1975) the subjects of the present study, eleven- or twelve-year-old sixth-grade students, are still cognitively immature (that is, they are still at the concrete reasoning stage) and therefore cannot yet master variable isolation and control skills. These conclusions are reinforced by the findings in Lawson & Wollman (2003), who studied how the transition from the concrete to the formal stage can be promoted. In that study it was also found that students who were at the concrete stage and took part in an intervention group in which they practiced inquiry skills were relatively more successful in performing cognitive tasks than their peers in the control group. Wollman (1976) argues that even young children possess an intuitive sense of variable isolation and control; in other words, a child can tell that a certain task requiring variable isolation and control is unfair, even though it is yet unable to formulate the more general rule. By having children experience concrete, understandable activities that relate to their previous knowledge, they can be helped to learn and absorb formal conceptions. These findings provide support for the principles of the CASE approach, which bring about an acceleration of the development of thinking. It is quite possible that it is these principles, which encourage cognitive conflicts, building up knowledge through experiencing concrete activities and connection with previous knowledge, interaction among students and the emergence of meta-cognitive processes in the course of the discussions that accelerated thinking in the context of the formal reasoning schema on variable isolation and control (Shayer, 2003).

Learning through inquiry is a method that fits the constructivist approach to science education, because the way in which it is implemented makes significant active learning possible. In the course of their work in the inquiry laboratory students have an opportunity to examine what they know in light of phenomena that cannot be explained with their existing knowledge, forcing them to rebuild the relevant parts of that knowledge and to interpret it.

Inquiry plays an important role in the standards project (National Research Council, 2000), where it is considered an important factor in the attainment of scientific literacy. In the standards document the word "inquiry" has two meanings (Bybee, 2000); (a) inquiry in the sense of understanding a topic, giving students an opportunity to construct concepts and mental configurations that enable them to explain the phenomena which



they experience, and (b) inquiry in the sense of learning abilities or skills. Among the inquiry skills enumerated by Bybee are: posing questions, formulation of hypotheses, planning and carrying out a scientific experiment, formulation of scientific explanations, communication with colleagues, and defending scientific arguments. In the present study an approach was presented which helps students improve their required inquiry skills by way of carrying out inquiry experiments involving, as an example, variable isolation and control.

The theoretical framework of social constructivism is expressed in the inquiry laboratory through the teaching method (Tobin, 1990; Lunetta, 1998). The theory of social learning stresses the fact that learning involves interaction with others and that conceptual development involves the use of language as mediator. Learning thus depends, at least in part, on interaction with adults and with one's peers. The theory of social learning highlights the importance of group work in the laboratory, which gives rise to a significant dialogue among the students, and between the students and the teacher, focusing on the concepts to be learned (Lunetta, 1998). Furthermore, the laboratory experience, during which students discuss ideas and make decisions by themselves, provides the teacher with numerous opportunities to follow their students' thinking as they talk to their peers about the meaning of what they are doing. A careful observation of students' activities and listening to their discourse will present the teacher with opportunities to ask questions and make comments within learners' "Zone of Proximal Development" (ZPD) (Vygotsky, 1978). In addition, the CASE program, based on cognitive acceleration, allows students to practice their inquiry skills in a more significant way and also makes it possible for them to overcome the difficulties they face when performing the inquiry experiments, whereas the NEW OUTLOOK program does not allow the students to practice their inquiry skills at all.

Conclusions and Recommendations

New standards in science education are being advocated to reflect the current vision of content, pedagogy, students' assessment of the classroom environment, together with the support necessary to provide a high-quality education for all students. We operate in an era in which there is a revival of the inquiry approach in science teaching and learning. Learning is more significant and more efficient when students possess well-developed meta-cognitive skills, that is, when they are aware of what learning methods are effective for them and are capable of exploiting them in order to attain better learning. Since it has been found that meta-cognitive abilities improve through in-depth learning (Thomas & McRobbie, 2001), it is expected that in the course of learning using the CASE approach, which makes it possible to focus more in depth on fewer subjects, students will develop meta-cognitive skills that will be expressed in the form of increased awareness of their learning methods and control over the processes and products they will extract from their learning.

As mentioned previously, the CASE teaching strategy possesses elements that make it appropriate for a teaching science through socio-cultural approach. According to this approach information has meaning only within the community that uses it (Lunetta, 1998). We agree, as well, with the claim that Science-Technology-Society (STS) approach is not merely about teaching interdisciplinary contents. It is much more than that, as Aikenhead (2004) explains the production of STS conceptual framework:

It (STS) requires the integration of two broad academic fields, (1) the interaction of science and scientists with social issues and institutions external to the scientific community, and (2) the social interactions of scientists and their communal, epistemic, and ontological values internal to the scientific community. (p. 9)

In the case of the sciences, the relevant community consists of the scientists who are working on the research that is taking place in the laboratory. Therefore learning also has to take place in the laboratory, where the same actions have to be carried out as those which the scientists perform. When they do research, scientists ask questions, formulate hypotheses, discuss and formulate explanations. The students who participate in learning via the CASE approach also perform all these actions. Therefore this is an appropriate environment for the learning of science, according to socio-cultural and STS approach.

In light of the findings in the present study we recommend using the proposed CASE program in order to make the learning of inquiry among primary school science students more efficient. Another recommendation is that teachers who are to use the CASE program should undergo continuous professional training so that they attain the requisite level of skill needed to produce the best results among the students who learn according to this program.



Note

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Appendix**Questionnaire on scientific exploration stories**

Dear student:

Below are three tasks that test if you understand one of the important concepts in scientific research. Please give a brief answer in clear handwriting.

.....

Task (1)

It is well-known today that a living thing can only come from another living thing, but in the past people had other ideas on this issue.

Many people used to think that a living thing can come from non-living materials. They thought that flies come from rotten meat, because they saw that many flies appear on such meat.

The Italian scientist Redi, who lived 300 years ago, did not believe that life could arise from non-living material. He therefore decided to test this hypothesis.

He performed a number of actions to answer the question. First, he observed that many flies fly close to the rotten meat before the flies appear in the rotten meat.

So he did the following:

He took 8 glasses and put meat in all of them. He then covered four of these glasses with soft linen, which allowed the air to enter but prevented the flies from entering. The other four glasses he left open (Fig. 1).

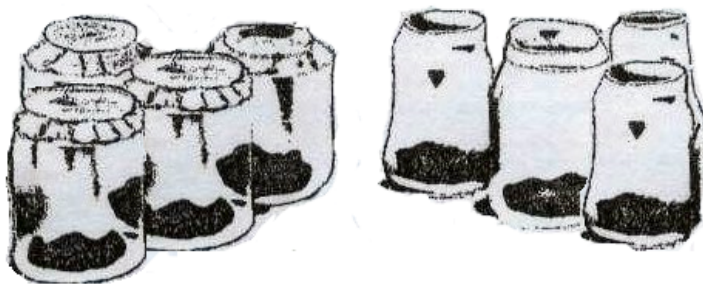


Fig. 1

1. What was the experiment's objective?
.....
2. What was the researcher's hypothesis?
.....
3. What was the affecting (independent) variable in the experiment?
.....
4. What was the affected (dependent) variable tested in the experiment?
.....
5. Do the experiment's results validate the researcher's hypothesis? Give reasons.
.....
6. Did the experiment contain controls? Give reasons.
.....
7. Note at least three constant factors in the experiment.
.....



- 8. Explain why it is important to be careful about constant factors in an experiment.
.....
- 9. Were there repetitions in the experiment?
.....
- 10. Why are repetitions important?
.....
- 11. What conclusions can be drawn from this experiment?
.....
- 12. Can the results of this experiment be generalized to other similar cases?
.....
- 13. Why was it important not to have examined just one factor?
.....
- 14. How would the conclusions have been different had we ignored one factor?
.....

Task (2)

One student decided to carry out this experiment:

He took some flour, added a small amount of fresh yeast .He then added water at the right temperature, mixed all the materials together and made a dough ball. He then made another dough ball like the first but without yeast. After a while he put the dough ball with the yeast in a glass of water at the right temperature (glass A) and the dough ball without the yeast in another glass of water at the same temperature (glass B) (Fig. 2).

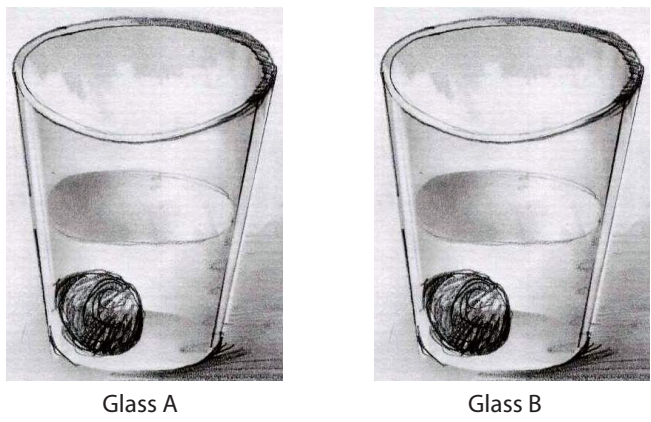
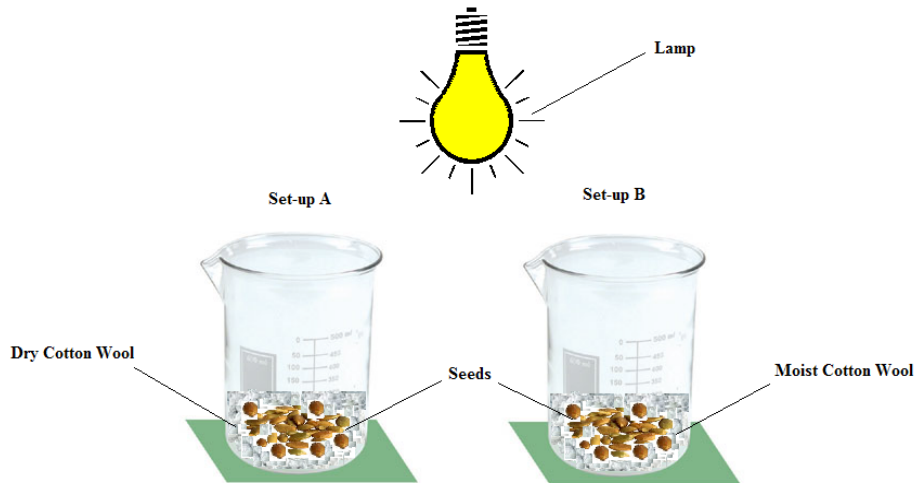


Fig. 2

- a) If the dough ball floats in glass A but not in glass B, what would be your conclusion?
- b) Which glass is the control? Why?



Task (3)

(Yip, 1999)

- a) If germination takes place in set-up B but not in set-up A, what would be your conclusion?
- b) Which set-up is the control? Why?

Task (4)

Planning an experiment:

Plan a simple experiment based on your scientific knowledge, one that contains an experimental system and a control system.

Question One: Can we trust the results of the experimental system as much when there is no appropriate control system?

Question Two: Why is the control system important for the experiment that you planned?

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