DEVELOPING THE METACOGNITIVE COMPETENCE IN STUDENTS IN AN INTERDISCIPLINARY CONTEXT

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Abstract: This article has a theoretical side as well as a practical one and our purpose is to present a complete perspective on acquiring the metacognitive competence in an interdisciplinary context. The interdisciplinary approach is obvious in a group project which got involved 10th graders from Moisil High school, Bucharest. As part of the project, students helped by their teachers and parents have built models such as an ecological solar house, a solar power station to charge electrical cars accumulators, a green office building with a solar lift, a solar fountain and minirovers. One of the challenges of this project was interacting with real objects from a distance through the integrated functions of the high school portal http://portal.moisil.ro. This has taken shape with the turning on of the gusher fountain, of the lighting system and the driving of the minirovers.

Keywords: metacognitive competence, interdisciplinary context, virtual interaction with real objects, green energy.

I. INTRODUCTION

Technology is progressing. Science drives its development. New jobs appear every day on the labour market, some we haven’t even thought about. Many of today’s students will do these jobs. They probably won’t be trained for these jobs since they haven’t been invented yet. However they will learn somehow.

“Nothing is more important in the twenty-first century than learning to manage change” [1]. But for this to happen, their thinking and knowledge must be adaptable. The skills they acquire in school should allow anchoring in the real world.

On the other hand, the teachers’ role is changing from keepers of knowledge to facilitators of learning. „...many teachers are comfortable delivering information. They view themselves as the keepers of the keys. But our job as educators is to facilitate learning, which derives from the French facile or from the Latin facilis, „easy to do”. Our job is to make it easy for students to internalise whatever information we are trying to impart to them – to make it personal, and to take that knowledge and use it to make their lives richer” [2].

Applying the principles of continuity and consistency in the school education reform in Romania in the curricular area of “Mathematics and Science” shifts the focus of the educational process towards the acquisition of skills and abilities.

Their role is to guide the teaching approach towards the student's final acquisitions. On the other hand, the list of values and attitudes shapes the axiological and affective dimensions of personality development in terms of the subject. Achieving all these things should be the aim of the teacher’s activity, representing an intrinsic part of his/her job.
Contextualized knowledge in the education process contributes to the development of the student’s personality. From this perspective, the teaching process achieved through the study of school subjects such as biology, physics, chemistry, should be geared towards one major goal - shaping the student’s personality according to the uniqueness of scientific knowledge [3, 4].

Unified scientific knowledge is a guarantee of correct interpretations of the various processes, phenomena, laws etc. achieved in the process of teaching-learning interconnected topics/concepts. The academic content presented by these subjects does not allow students to form a unified vision on the concepts, thus distorting the student’s integrate development.

Green energy is one of the concepts which can be approached from an interdisciplinary perspective. The term green energy is used for the energy provided by the environmentally friendly sources. They are also non-polluting because they have lower carbon emissions. We can include here the solar energy, the wind energy, the hydro and geothermal energy.

At present, the electricity generated by renewable sources is becoming increasingly available, thus reducing the environmental impact while increasing the energy independence.

The Sun is undoubtedly a vast source of energy. In one year, it sends to Earth 20,000 times the energy the entire population of the world needs. In just three days, the Earth receives from the Sun an amount of energy equivalent to the one existing in fossil fuel reserves. Solar energy is the source of all energy used by mankind. Heliothermic potential equals over 12 million billion tons of conventional fuel per second. Of this 80% is consumed by water evaporation, 16% by photosynthesis, and the remaining 4% would ensure the replacement of all fuel consumption for the population of the Earth [5].

Biology and chemistry, but especially physics focus on the understanding of nature. These subjects addressed strictly in terms of specialized scientific knowledge do not offer students a unified view of things, being considered isolated. Achieving unity in the diversity of scientific knowledge, which will foster the understanding of the world, relates directly to the application of interdisciplinary connections.

II. INTERACTIVE TRAINING AND THE STAGES OF DEVELOPING THE METACOGNITIVE COMPETENCE IN ADDRESSING THE TOPIC "DISCOVER GREEN ENERGY"

An effective teaching strategy for achieving a specific objective requires the implementation of the general principles of planning a learning activity – the continuous development of the personality and teaching methods adjusted to a given context.

The teaching strategy focuses on how to achieve a specific process and is strictly determined by its nature, namely its constituent elements, which are justified and applicable [6].

The training activity meant to develop the metacognitive competence is a symbiosis of teaching strategies, which was achieved through four basic stages.

The stages of knowledge (declarative, procedural, strategic), like the four basic types of knowledge activities (to know, to know how to do, to know how to be, to know to become) in the educational process, have their own specific value in the context of intellectual development [7]. There are many interactions, intersections and overlapping between the stages of knowledge and the types of knowledge activities, leading to formation of the metacognitive competence.

The networking between the stages of knowledge and types of knowledge activities in the educational process generates the development stages of the metacognitive competence.

The four development stages of the metacognitive competence may be characterized as follows:

a) The stage of fundamental knowledge. This first phase is associated with the verb "to know". Thus, the learner must first receive an amount of information and instructions that will build the source for the acquisition of procedures or problem solving strategies.

Thus we distinguish between two kinds of knowledge: declarative knowledge and procedural knowledge. Rational learning, which, through training and education, is designed and intended to work as an integrated process finds its continuity in the development process. Therefore, learning activities
should aim to continually develop the student's mental skills. "The man’s drive to know, the acquisition of certain knowledge determines a certain spiritual construction, which causes some changes in the external character of personality. But the formative efficiency of culture lies in how culture is assimilated and in the degree of the students’ active participation in the assimilation of knowledge" [8].

b) The stage of functional knowledge. It is not enough for the students to know some scientific facts, but also to be able to apply them in certain situations. The second stage in the development of the metacognitive competence is associated with "to know how to do" activities, which transform fundamental knowledge into functional knowledge, also called by Anderson procedural knowledge. In this regard, we note that "engaging students in the process of knowledge stimulates the formation of mental operations, those intellectual processes by which students process, interpret, relate similar information, ensuring new understanding of knowledge" [9]. Thus, to solve a problem, the student needs both declarative knowledge for understanding the significance of the problem data and procedural knowledge, namely the "problem solving strategies" [10].

c) The stage of internalized knowledge. In the third stage, knowledge is internalized and becomes functional abilities, skills, behaviors, and results. This stage which is characterized by "to know how to be" activities expresses what the student is and it focuses on how to know and understand life situations, to react and act, to behave in unfamiliar situations. That is why M. Bocos believes that “the interiorization process is one of the most important phenomena of mental life, a process through which objective elements are transformed into an intersubjective reality. To ensure the interiorization process it is really important to foster a mental and spiritual readiness and to trigger emotional tensions through attention and concentration [11].

These steps represent the internal resources behind the development of skills and for their expression the significant situation is inseparable.

A significant situation is a real life situation, consisting of several problem situations and having an interdisciplinary character. It is a functional situation on which the practical solution depends and "the problem situation is a phrase that designates all the training situations characterized by the fact that students encounter an obstacle, a difficulty during the practical or theoretical knowledge activities" [11].

d) The stage of externalized knowledge. Solving any significant situation involves the transfer of the three types of knowledge in the "to know how to become" activity. At this stage, the student operates with the internalized, personalized, interrelated knowledge and proposes strategies for action and applying them he develops and implements a work project, he evaluates and adjusts his own activities [12, 13]. The "to know how to become" activity is an activity of synthesis during which the student's internal resources are externalized through some concrete actions, performed in a significant situation.

The four stages in the development of the metacognitive competence served as support for the application of interactive training based on the active/interactive methods of shaping the student’s personality.

So, we have started a group project, with 10th grade students from Grigore Moisil High School, Bucharest, the teachers, the students' parents and the local community. At the beginning we intended to familiarize the students with green devices such solar cells and their applications in order to perform the theoretical study.

During this stage of the research the students helped by the teachers and parents made some simple applications such as a solar house, a solar lift, a solar power station for toy car chargers. One of the challenges was to build a solar gusher fountain which will be held in the schoolyard during the summertime and now it is held in the Physics lab. The great challenge was to build robots able to work on Mars surface. The first rover was named Opiphicus and the second one Spiritus. Moreover, we believe that humanity will be able to build the whole town from the photo on planet Mars. The team learned how to interact with these green devices from distance, via Moisil Live!

The aspects from the activities could be found at http://portal.moisil.ro/playenergy/Documents/Forms/With%20File%20Size%20Column.aspx
Username: vizitator
Password: vizitator. [14].

In this context the project progress is:
a. Definition of the tasks
• Perform some experiments with solar cells
• Develop some applications of solar cells

b. Organizing and planning
• Choose the teams
• Brainstorming to find the best ideas for building green tech (solar) devices

c. Designing and making
• Participate in making the solar house, solar lift, solar power station for toy car chargers, the gusher fountain and the robots Opiphicus and Spiritus Sanctus. (simply: Moisil Town!)

d. Presentation and interaction
• Upload the materials on the portal
• Interact with Moisil Town from a distance via Moisil Live from portal.moisil.ro

e. Feed-back and evaluation
• Present solar devices in some national and international conferences and contests
• Won some important prizes

If we refer to the interactive training activities, they involve a joint effort from both the teacher and the student and include laboratory experiments, heuristic conversations, exercises, problem solving, modeling, computer assisted training, conceptual maps, Venn diagrams, demonstrations, observation, conversations, etc.

Thus, the development of the metacognitive competence in “Discover green energy” project was achieved as follows:
The first stage – the development of fundamental knowledge, includes all the theoretical knowledge that students acquire in “Discovering green energy” ("to know"). Fundamental knowledge through applications becomes functional knowledge ("to know how to do"). Functional knowledge through exercises, experiments, investigations becomes internalized knowledge ("to know how to be"). These three steps represent the internal resources the student needs and being deployed to solve a series of situations, problems they become externalized knowledge, namely the student demonstrates the proficiency level.

The training stages are mutually interdependent and represent an ongoing cycle, which by using different methods, forms, ways of learning, results in increasing the performance identified by indicators.

Scientific knowledge and the four stages of development of the knowledge competence specific to “Discovering green energy” determined us to use interactive training activities in which the emphasis is on building individual knowledge so that students become active subjects of an educational activity directed by their personal educational needs. This activity allows them to build their scientific knowledge and to mold their own personality.

The teacher’s role in interactive training is to propose students activities which actively get them involved and determine them to unlock and fulfil their potential looking for something new, and achieving it through their own intellectual efforts. The major objective in interactive training is focusing on individual or collaborative learning activities, the teacher helping his students to shape personality, to develop their sense of responsibility and self-confidence [7].

The development methodology proposed by interactive training doesn’t focus on the knowledge-teacher relation (as in traditional education), but on the student-knowledge relation. Thus, the student is viewed in terms of his potential to build scientific knowledge, to learn, to be and to develop his intellect, his complex personality and knowledge is not viewed as information memorized and reproduced, but as a support for the development and construction of new acquisitions by the student himself.

Some of the solar devices applications are the eco-house and the power station for toy car chargers realized in „Grigore Moisil” High School from Bucharest.

According to M. Bocos the main conditions to be met by interactive training in order to be labeled as “effective” vision would be: constructivism, interactivity and metacognitivism [7].

Constructivist training is based on techniques which underlie knowledge and provide new constructivist developments. There is authentic knowledge only when the students build it themselves, developing answers to the questions they ask themselves, adapting their behavior to the unpredictable situations they face in life. It is very important that the information is integrated into knowledge and
the knowledge is integrated and linked to cognitive schemes that substantiate knowledge. These successive integrations are the processes which allow us to avoid the accumulation of scientific information unnecessary for the student.

Some problems appear: if the solar cells are fixed on the car, this is not able to move because of the weight. That’s why it is better to make a solar power station for car chargers.

Also effective training must be active and interactive, that is to create an interactive learning environment appropriate for establishing interactions between students, between teachers and students and between students and the subject of study. Active and interactive training involves managing your work and effort, verbal and intellectual changes, conviction and enthusiasm, autonomy; it is a way of training that promotes the construction of new knowledge.

During the construction of the ecological office building, the students have discovered the secrets of interior lighting installations. To use 12 V powered LEDs, this being the amount supplied by the solar panel charger, students have completed the wiring in a way similar to that of a real building.

Training is not possible without students performing an independent and motivated cognitive activity. Thus, interactive training is guided by metacognition, which means that “all the cognitive activities through which the subject understands and manages better his own instruments of knowledge” [15]. We are talking here about metacognition in relation to the student's ability to manage his cognitive activity when having to solve a problem. For students, metacognitive training is a way of self-control, of self knowledge, of improving their working techniques, of making progress [16].

One of the challenges is to build a gusher fountain. It’s a long journey from the first probe of our solar gusher fountain to the final design and the interaction with it from a distance.

Metacognitive training supports the development of metacognition and self-control skills and the teaching methodology is just an external aid in the mental construction of scientific knowledge [7].

For training to become metacognitive, it should meet the following conditions:
- to start from the idea that students are able to build knowledge and skills;
- to create an incentive framework for the development of knowledge and skills through student-student interactions, student-teacher and student-studied topic;
- to diversify all functional stages of knowledge: declarative, procedural and strategic [17, 18].

In interactive training, learning and intellectual development seeks the effective, intense, deep and full involvement of students. A lesson, a didactic activity is dynamic when it is based on a heuristic approach to stimulate the interest, curiosity and desire to learn and act. Heuristic approaches are the most productive in the metacognitive process; they orient the learning process towards the development of school skills in students [17].

Heuristic approaches, starting with perception – the basic act - and ending with the formation of more complex and abstract notions/concepts, theories of the knowledge process characteristic of scientific disciplines, heuristic activities are still considered a problem solving exercise involving the continuous practice of thinking operations.

Addressing the topic “Discovering the green energy” in an interdisciplinary context Physics, Chemistry and Biology, the heuristic approach must be problematization and discovery. Problem-solving consists in the creation of contradictions, the so-called-problem situations that students need to identify and try to solve them.

The main objective of problematization, as a method of teaching is to train the students’ capacity to identify problems, to ask themselves questions, to formulate and solve problems and problematical teaching aims to teach the students to think [12].

A new problem appears in our project: the photovoltaic cells have to be moved under maximum solar illumination to reach a greater efficiency. How? By recycling some servomotors from the old school printers, then innovate a way of coupling them with the PV cell. The next step is to use some sensors of light (photo resistors coupled with a data acquisition board and a computer) to decide when to change the incline of the PV cells and then to develop the software for analyzing the sensors indications, to make the decision and move the servomotor.

Placing students in a position to reflect, to ask and wonder, to seek solutions and to check them experimentally and logically, problematization and discovery represent for “Discovering green energy” ways of knowing reality at a level as close as possible to the scientific knowledge.
Problem-solving as a heuristic technique/method is interconnected with learning through discovery and can be accomplished through any method of training. The essence of problematization is the "problem", designing, building and solving it. The problem is based on a cognitive conflict generated by the relation between the known and the unknown, which also generates the contradiction. The problem, as a set of known and unknown elements, somehow connected, has as its main element "problem - question".

Problem - questions are incentives for the advancement of knowledge. The bridge between questioning and discovery is a "problem-situation" and all problem-situation are "significant situations".

Problem-situations and significant situations are the necessary conditions to support the effort of thinking that makes progress towards competence. So students have to be trained in activities of problems and situations formulation – problem situation, search, investigation, experimentation and research situations which foster active and interactive learning based on creativity and discovery.

A problem-situation designates according to C. Cucos a contradictory situation, conflict arising from living two realities at the same time: previous experience and facing the unknown. The conflict stimulates the student to search and discover new solutions, to use his intuition [19].

There are several types of problem-situations, which appear when [20]:
• there is a disagreement between the previous knowledge and the new requirements imposed by the solving of a new problem;
• the student must choose from a chain or system of knowledge, sometimes incomplete, only the information that will be necessary in solving the situation, and will fill in the missing data;
• the student is faced with a contradiction between the theoretical solution and the difficulty of implementing the theory in practice;
• the student is required to apply previously assimilated knowledge in new conditions.

The teacher should encourage the maintenance of an active attitude, maintaining “the optimal level of uncertainty” as a routine, tedious task does not stimulate action, as well as a task with many unknown things, which predisposes the students to stress and inevitably leads to discouragement [19].

And now, the interaction with real object from a distance. In figure 2.1 one can see the little rover named Moisil. It can be driven from a distance via Moisil live: http://portal.moisil.ro/Pages/moisil_live.htm. Like Spirit and Opportunity on planet Mars.

![Figure 2.1. First rover on Mars](http://portal.moisil.ro/Pages/moisil_live.htm)

The formative value of these methods is subject to:
• the development and consolidation of cognitive structures;
• fostering the spirit of knowledge;
• an active working style;
• fostering autonomy and courage in support of one’s position.

Using these methods we meet the following requirements of modern education:
• forming sound knowledge right from the start, not after multiple repetitions;
• developing creative, productive thinking skills, the ability to offer more solutions to the same problem;
• acquiring new knowledge but also methods of knowledge;
• developing their moral features under stress [21].

Problem-solving and discovery allow the use of mental strategies and activities that stimulate the thinking operations: analysis, synthesis, comparison, abstraction, etc., the students’ judgments and reasoning, enabling them to acquire knowledge independently.

The act of teaching and learning involves the activation of mental processes, transformed into teaching steps, steps through which the student learns to learn, to know, to do and to be. He follows the steps of knowledge through active learning techniques [22, 23].

The diversity of methods and procedures used in the teaching process represents the teacher’s professional competence, this being how he develops the students’ interest, creativity and motivation for learning.

In order to achieve the conditions of interactive training it is necessary to plan the development of the metacognitive competence.

Thus, during the design process of the development of the metacognitive competence we have emphasized three important moments: setting objectives, organizing the educational process and establishing the teaching strategies.

Specifying the educational objectives is, according to C. Cucos, the fundamental condition of correct lesson planning [19]. Therefore, three objectives were established for the development of the metacognitive competence:

• forming a system of knowledge, skills, abilities and skills;
• exercising the acquired knowledge system in simple situations;
• demonstrating the problem solving abilities of problem-situations and significant situations.

The organization of the educational process based on the set objectives is directly related to:

the selection and design of educational content, establishing active/interactive methods of teaching and learning, the psycho pedagogical conditions and the methods of assessment and evaluation.

III. CONCLUSIONS

The devices presented in this paper won some prizes in national and international competitions like:

• Third Prize to the International Contest Play Energy - Enel, Romania;
• The Excelency Prize “Intel®Education“ – 1000 USD, – „The project: Solar fountain”, – Cîrmis Andrei, Popescu Remus, eng. Ion Neacșu, Dragoș Munteanu – ”Grigore Moisil” High School – Bucharest;
• The Popularity Prize “SIVECO”, - „The green technology for sustainable economic development”, – Ana-Maria Luchian, Florina Aidoiu, Daniel Lupu, Mădălin Ene, Mihaela Garabet– ”Grigore Moisil” High School – Bucharest.

The project’s results were presented in the Microsoft Partners in Learning European Innovative Education Forum, held in Berlin, March 23-25, 2010. Here it took the 2nd Prize for Innovation in Community and the qualification for the Worlwide Innovative Education Forum from Capetown, South Africa, October 2010.

The practical values of interactive training are manifested by centering the teaching activities on the individual and collaborative learning of high school students, the teacher being a mediator and helping students to shape their personality, to develop responsibility and self-confidence.

The development of the metacognitive competence is a long process, which undergoes four stages: the acquisition of basic knowledge, its transformation into functional knowledge, the awareness of functional knowledge through problem-solving situations and the expression of the competence in significant situations.
The methodological benchmarking of the development of the metacognitive competence, modeled in a functional system, focuses on: organizing the educational process according to the objectives, the teaching strategies set and accomplishing the process in the four stages of competence training.

References