DEVELOPING THE ABILITY OF LEARNING AND THINKING AT A HIGHER LEVEL AT SCIENCE CLASSES CREATIVE CHALLENGE OR INTELLECTUAL RISK?

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Abstract

In modern school, the student should become the meaning and the purpose of the content that will introduce him/her into the world of competition and competence in order to enable successful communication with it. How can we draw school nearer to the student? How can a teaching lesson become a workshop in which new ideas, creative solutions, new forms of research and new knowledge are being intercrossed?! To create and develop modern education means to realize objectives that would reflect its sense. In current education, the hierarchy of values that should be set and implemented is asymmetrically positioned.

The research that has been done in this paper aims to investigate the introduction of practical teaching and application of reforms in teaching biology in a few schools in Stip, R. Macedonia. Data were collected from semi-structured interviews made with 11 experienced teachers of biology.The results showed that teachers occasionally introduced a small number of enhanced instructional strategies that explicitly match the formal curriculum in their classes, such as: presenting, analyzing and generalizing experimental results from practical teaching of biology in various forms.

However, teachers have used fewer strategies that target encouraging higher level thinking, such as to induce students to ask questions or to learn about problem solving strategies used during lessons. Although biology is considered to be a relatively well established subject in the schools in the Republic of Macedonia, significant differences were identified between teachers regarding the use of rich teaching strategies during lessons, their confidence in the application of ICT in teaching, and their beliefs about the abilities of students to develop the ability to think at a higher level. Teachers often consider reformed teaching as being more an idealistic method than pure school practice. It is therefore necessary to continue to work in this field. Teachers should have training and practice so that "higher level thinking" becomes an integral part of teaching classes in natural sciences, especially biology classes.

Key words: modern school, reforms, teaching biology, teaching strategies, higher level thinking.

INTRODUCTION

To open the issue of the current context in which modern education is reformed and promoted means to identify the factors that define the essence of young people’s integrationinsociety. The basicsthat create theprocessofeducation can berecognized inthe impact offamily, socialgroups, schooland media that createthesystem of values.Thecreate community of factors that are essential for the developmentofa student. Hence, first parents andsocialsetting,and then school, help youngpeople toaccept changes more easily.

The school is the mirror of a society. To create and develop modern education is to realize goals that will reflect its meaning. In current education the hierarchy of values to be set and implemented is asymmetrically placed. In modern school, the student should become the meaning and the goal of the contents that will introduce him/her into the world of competition and competence, in order to enable successful communication with him/her.

Since 1997 the UNESCO Paris International Conference the fundamental goals of education have been clearly defined. They are entirely related to the student who needs to learn in order to acquire knowledge, to work, to live, and to live with others. Our educational system, in terms of the implemented projects, can boast with the statistics and estimates which include us in the developed European systems. The reality, however, is slightly different. The essence of all the reforms in our educational system so far has imposed form –instead of contents, needs instead of solutions.

Attempts to introduce projects that will encourage creative teaching are an excellent base for the development of modern school. Teaching tools allow the application of methods and techniques that can stimulate the development of critical and creative thinking in students. But what is fundamentally an important and, unfortunately, still unsolvable problem, are extensive educational programs which, instead of involving students in the process of education, increasingly pull them away from it.

Sad is the assessment of internal evaluations of students, showing that educational programs (for the most part they were last reformed in 2002) offer too much theory, unnecessary statistics, outdated data ... Such a content of teaching is the main reason why students are increasingly out of school, and the number of their absence is increasing. The problem becomes even more complicated if we know that there is a growing tendency to increase the number of compulsory “optional” subjects, not taking into account the mental and physical capacity of students, especially in lower grades. Can a second grade pupil have the power of concentration during five teaching lessons, three times a week, or can six graders preserve their mental strength during six lessons, again three times a week?! It is clear that each pupil has his/her personal potential. The purpose of school is to detect and direct that capacity, through thinking and motivation, through development and stimulation.

How to make school more accessible to the student? How can a lesson become a workshop that where new ideas, creative solutions, new forms of research, and new knowledge will cross each other’s path?! The project "Computer for Every Child" was to bring us closer to the tendency of students developing their creative potential, and of our adopting modern trends in education. Practice has shown that the form has not brought us to the content and essence of school. No one listens to parents’ voices that almost lost the battle with their children in trying to explain that the computer cannot replace daily routine, immediate communication and socialization. No one respected the experience of teachers who replaced frontal communication, group presentation, and immediate debate with monitors facing students as a true picture of alienation from school and a symbolic distancing from it.

Each school needs its own small "computer center" that will be used for certain lessons and for certain purposes. Teaching sometimes requires the usage of information technology. But making the student the prisoner of the really small space of the classroom, engrossed in daily play and struggle to take the teacher in order to provide personal entertainment and recreation, becomes a more serious problem. The fact that younger generations spend their day and night in the Internet reality they live in and in which they are being nurtured. Tired, unwilling to engage in active work, with physical deformities as a result of habit, homes being turned into schools, and schools into homes…or rather, into places for a good sleep. Modern school should be directed exactly towards the "awakening" of the creative mind, stimulating thought, of speech, of literacy, the continuous (re) creation of lasting values of culture and life.

Will we ever count the consequences of major endeavors that carry risk of losing the young generation, their ideas, abilities?! Will we manage to affirm habits of learning and motivation for developing the spirit, as a prerequisite for survival and tradition?! The society is in crisis, not education. It is only its logical consequence. Modern education is still waiting for its realization. With reforms that will mean creating natural conditions in schools, qualitative and reduced teaching content, creative freedom for creating new ways of learning, intensive socialization, respect for values that will preserve the family, promote the school and develop the society.

Only then will we be sure that we created generations for whom education is a reliable and powerful intellectual challenge rather than a risk that will take away the greatest resources of our development. Because they are "our children" and our future, are they not?

THEORETICAL FRAMEWORK

A major goal of science education today is fostering students' intellectual competencies, such as independent learning, problem-solving, decision-making and critical thinking. Over the past few decades, these ideas about the objectives and methods of science education have prevailed within the community of science educators. However, the change instigated at the school level has been very slow, and most studies today still take place using routine methods, i.e., the teacher delivers content or the students algorithmically solve many exercises.

Dancy and Henderson (2007) claim that although terms such as reform, change and improvement are frequently used in the dialog on science education, these terms are not clearly defined and no consensus exists as to their exact meaning. These authors suggest a comprehensive framework for articulating reform-based science education, consisting of two parts. The first part relates to educational *Practices***,** namely teachers' behaviors regarding **1- Interactivity, 2 - Instructional decisions, 3 - Knowledge source, 4 - Students success, 5 - Learning mode, 6 - Motivation, 7 - Assessment, 8 - Content, 9 - Instructional design and 10 - Problem-solving.** Regarding the aspect of Instructional decisions, for example, while a reform orientedscience teacher shares decisions with his/her students, a conservative teacher decides exclusively on his/her own. Regarding the aspect of content, alternative instruction means that a teacher explicitly teaches students how to learn, think and solve problems, in addition to teaching scientific content; in contrast, a teacher in a traditional class deals mainly with facts and principles.

The second part of the framework mentionedabove describes teachers' Conceptions, namely attitudes,goals and other similar types of mental behaviorregarding science education. This part relates toteachers' views on 1) Learning , 2) Expertise, 3) Knowledge,4) Nature of science, 5) Role of school, 6) Students 7) Teacher'srole, 8) Diversity, 9) Desired outcomes, and 10) ScientificLiteracy. In the aspect entitled Role of school, for example, regard school as a place to help students develop asindependent thinkers and enrich their personal lives,educators holding traditional views of education oftenregard school as a place to prepare students for theirfuture roles in the workplace and society.The distinction between teachers' Practices andConceptions, as Dancy and Henderson (2007) suggest, isvalid and useful, because a teacher might hold veryprogressive views about education, but in practice useconservative teaching methods; such a situation couldbe a result of various factors such as a teacher's lack ofcontent or pedagogical knowledge, difficulties inadapting to change, or pressure at school. We will discuss this point in more detail later in the paper.

TEACHING HIGHER-ORDER THINKING IN THE SCIENCECLASS

Questions like what constitutes good thinking orhow to foster students' thinking in school in general,and in science lessons in particular, have beenincreasingly discussed in the educational literature overthe past few decades (Beyer, 1988; Costa, 1985; Glaser,1984; Pogrow, 1988; Sternberg, 1987; Zohar, 1999,2004a; Zohar and Dori, 2003). Resnick (1987) suggestedthe concept of 'higher-order thinking,' which avoids aprecise definition of thinking but instead points towardssome general characteristics of higher-level thinking, asfollows: higher-order thinking is non-algorithmic,complex, yields multiple solutions, requires theapplication of multiple criteria, self-regulation, and ofteninvolves uncertainty.

Costa (2002) mentions two advantages of infusing the teaching of thinking skills into teaching science. First, skillful thinking cannot be performed in a vacuum – there must be something to think about. Second, the nature of scientific inquiry imposes certain constraints on problem-solving processes; scientific problems, in which the control of experimental variables is paramount, differ from social and aesthetic problems in which ethics and artistic judgment play a significant role.

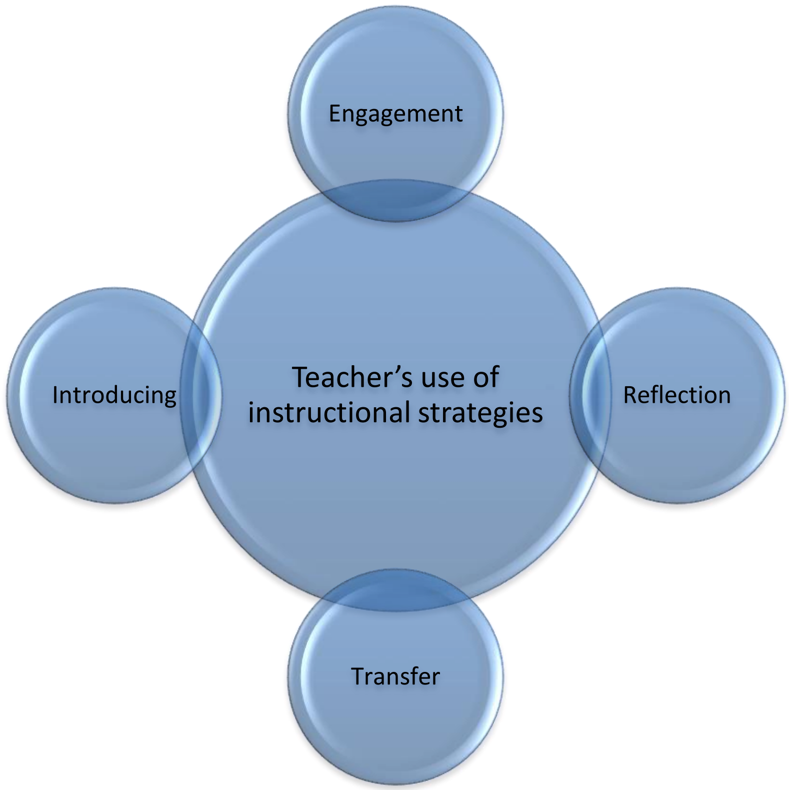

Figure 1: Teacher's use of instructional strategies

Swartz and Parks (1994) suggested four basic components that should be included in designing theteaching of problem-solving strategies in the science class: 1) explicitly *Introducing* a thinking strategy to thestudents in the context learning of the subject matter; 2) actively *Engaging* the students in the suggested strategy; 3) *Reflection* on the strategy after gaining some experience in using it; and 4) *Teaching* for *Transfer*, namely showing the students how the specific strategy can be used in other related situations. Figure 1 illustrates this model.

So far we have seen the potential of scienceeducation as a platform for developing students'thinking skills. Unfortunately, science studies are oftendictated by a rigid syllabus or the obligation to preparestudents for various types of tests, such as regional andnational surveys or final high school exams. In Macedonian,for example, high school students must takematriculation exams in all subjects learned inhigh school. Since getting high scores in these exams isa key criterion for enrolling into higher education,particularly in areas such as engineering or medicine,most of the teachers and students focus their efforts onlearning towards these exams. Indeed, the requiredcurriculum demands that students be able to deal withnon-routine questions and tasks both in theoreticalstudies and lab work. Yet, questions exist as to howteachers address the task of fostering students' thinkingskills in science class. Since, as we noted earlier, bothteachers' beliefs and behaviors play an important role inthe educational process, in this study we aimed atexploring questions such as:

What are teachers'conceptions about reform-based instruction versustraditional teaching of science?

What teaching methodsare actually used in science class using these twocontrary methods?

The significance of this study lies in its potential tocontribute to the literature and to educational practicerelated to teacher training, with special focus oninstruction aimed at promoting higher cognitiveprocesses in the classroom.

METHOD

The study involved the participation of 13 biology teachers, ten females and three males, most of them having over 14 years of experience in the teachingprofession. Each participant taught biology in adifferent school; all of the schools were located in orclose to a central city in Shtip.Although these schools serve a heterogeneouspopulation – from students living in affluentneighborhoods to students coming from relatively low income families, biology students are quite ahomogeneous group within these schools because theyall learn the same curriculum and take the same officialmatriculation exams. The gaps between students indifferent schools cannot be extreme, because in Macedonia,as in many other countries, biology is frequentlyregarded as a subject aimed only at high-achievingstudents, an 'elite' subject in science studies (Angel et al.,2004; Osborne et al., 1998; Woolnought, 1994). Wedon't claim to have taken a random sample; instead, weselected the participating teachers to represent fairly wellthe profile of experienced biology teachers countrywide.

A similar approach was adopted, for example, byDancy and Henderson (2005), who explored the barriersin using researched-based instructional strategies inteaching biology by conducting semi-structuredinterviews with five well-respected, tenured biologyfaculty members from different institutions. In ourstudy as well, most of the teachers were regarded asimportant figures in their schools, often in charge ofpreparing the biology class for the matriculation exam.Huberman (1989) described teachers having this type ofbackground as being in the 'divergent period' of theirprofessional development, characterizing them asfollows: "Some teachers describe this as a period ofexperimentation and activism as they develop their owncourses, try out new approaches to teaching, andconfront institutional barriers. Yet, others see it as aperiod of self-doubt and reassessment; many teachersleave the profession at this stage as their level offrustration with the system reaches its peak."We are aware of the limits of basing the study on arelatively small sample; however, we see an advantage infocusing the study on teachers from a specific discipline,in particular a relatively well-established field likebiology, and from schools located within a relativelysmall geographical area. This enables concentrating thediscussion on the knowledge and attitudes of teachershaving a common professional background whilereducing the influence of factors related to thedifferences between the disciplines or the diversity ofthe population served by the schools. It is also worthmentioning that the study addressed the teachers duringtheir regular work throughout the school year, ratherthan under special circumstances, such as teaching anew curriculum or participating in an in-service course.Therefore, we believe that the context of the studydescribed above contributed to the validity of the outcomes.

DATA COLLECTION AND ANALYSIS

To this end, the main data collection method involved holding semi-structured interviews with the teachers individually in their schools. The study adopted the qualitative methodologyaimed at obtaining a holistic understanding of theparticipants' viewpoints on the issue of higher-orderthinking in teaching biology, how they understand thisconcept, and what stays beyond their externalexpression of their behavior.The principal value of interviewsis that theyoffer a rich source of data that provides access to howpeople account for their understandings and attitudesabout everyday experiences.

The interviews, which lasted about 120 minutes,started out by presenting the teacher with a list of 20strategies often used in teaching biology, such asformulating a research question, controlling variables,ordrawing inferences from an experiment. Theseinstructional strategies were selected from the currentliterature on biology education and materials used inteachers' courses in Macedonia. Theinterviewees were asked to comment on each strategy,for example, the extent he/she uses it in class, itsadvantages and disadvantages, or where he/she hadlearned it. The interviewees were also encouraged to addadditional strategies they knew or used. Theconversation, however, did not adhere to this formatbut rather developed into divergent directions accordingto each teacher's interests or preferences. Theparticipants were asked about their instructional goals,current and past instructional teaching experience, orattempts to make changes. The interviewer, the secondauthor of this article, has herself been a biologyteacher for about 14 years. To create a relaxed atmosphere, theinterview started with an explanation to the intervieweethat the study is about teaching biology in general, andthat there is no intention to evaluate him/her in anyway. The fact that the study is based primarily on whatthe teachers said without an attempt to evaluate theteachers in their practical work in the class is limiting onthe one hand, but also advantageous on the other; sincethe interviewees were not in any position of beingjudged or at risk in any way, they could reflect freely ontheir teaching and honestly express their views. Webelieve that this approach encouraged the teachers totalk about their successes and their failures, rather thanattempting to present themselves at their best.

TEACHERS' USE OF REFORM-ORIENTED INSTRUCTIONAL STRATEGIES

As previously noted, one of the main means usedby teachers to enhance cognitive processes in class isapplying diverse instructional strategies. At thebeginning of the conversation, the interviewer showedthe teacher a list of 20 strategies to enhance sciencelearning and suggested that they talk about thesestrategies. The teachers were asked, for example, if theycould indicate to what extent they use each strategy intheir class on a four-level scale (never / seldom / often/ very often), or express their opinions about theeffectiveness of the various methods. The intervieweeswere also encouraged to cite additional strategies theyknew or used. However, this was just a starting point forthe discussion, which developed in divergent directionsaccording to each teacher's interests or preferences, asdetailed later in the paper.

The mean frequencies the teachers attributed tousing each strategy are listed in descending order inTable 1.It can be seen that among the strategies marked bythe teachers as being the most useful in teaching biologywere (ranked 1-4): generalization of biological conceptsbased on experimental results; teaching diverseproblem-solving methods; guiding studentssystematically to justify their solutions to a problem ortheir decisions; and presenting data in diverse forms, i.e.,graphs, tables or texts. These results, as illustrated in Figure 1, are not surprising because the skills mentionedabove are required either in formal paper-and-pencilexams or lab exams. It should be noted, however, thatmost of the teachers often refer to the term ‘problemsolving’as solving standard computation exercises. Incontrast, the teachers marked instructional strategies(ranked 17 and 18 in Table 1), such as asking students toformulate their own questions or learning throughteamwork, as being much less important. It is alsoworth mentioning that the teachers marked moderate use of strategies related to fostering reflection (between“often” and “seldom”), such as explicitly discussingthinking strategies used in class with the students, orasking the students to state the difficulties theyencountered and explain how they resolved them.Beyond the discussion of the specific 20instructional strategies mentioned above, only two orthree of the 13 teachers who participated in this studycited the development of students' thinking skills asbeing a major objective in teaching biology or presentedexamples of how they were actively attempting toachieve this goal. One of these teachers said thefollowing:

“I don’t allow them to answer quickly becauseif I do, they won’t have time to think. First Iforce them to think: I don’t accept any answer forabout two minutes, for example… the answermust be the result of the thinking process, andthinking requires time.”

Another teacher said:

“A student asks a question and I ask three…in the beginning, they are in shock, and I explain:never mind, I want to understand correctly whatyou are asking, to find out the answer from you,because sometimes after three questions you already know it by yourselves.”These examples illustrate cases in which theteachers regard students’ thinking as an important issuein it. However, this was not the common situation.More often, teachers consider problem-solvingstrategies as a matter of efficient learning. The followingcomments reflecting this perspective were noted in theinterviews:

“Thinking strategies are not methods forsolving a specific question but are ratherorganizational methods; if you are well organized,you don’t waste time and can concentrate on thesubject matter.”

Or:“Efficient working methods avoid redundantwork and add to understanding the content.”

Another view expressed by the teachers was thatproblem-solving strategies are intended to raisestudents’ confidence. The following quote demonstratesthis point:

“I prepare a lot of charts for them how tosolve a question: Do this in this case, do that inanother case… what to do first and what later…

The students love having strategies. They do not always know how to use them but they feel moreconfident if they think they have strategies.

Table 1: Teacher’s use of instructional strategies aimed at fostering higher-order thinking in biology (n=13).

Rank	Strategy	Mean Frequency*
1.	Presenting data in diverse forms, i.e. graphs, tables or texts	3.24
2.	Guiding students systematically to justify their solutions to a problem or their decisions	3.95
3.	Teaching diverse problem-solving methods	3.67
4.	Generalizations based on experimental results	3.40
5.	Asking for students explanations’ before teachers’ explanations	3.26
6.	Stating the strong and weak points of different solutions to a problem	3.47
7.	Linking what is learned in physics class to other scientific fields	3.34
8.	Predicting the results of an experiment or a theoretical solution to a problem and providing justifications	3.12
9.	Asking students to verbally present the thinking stages they used in solving a problem	2.15
10.	Guiding students to add their own examples	2.39
11.	Presenting conflicts: facts or examples that conflict with students’ previous knowledge and intuitions	2.28
12.	Discussions of questions to which the answers are vague	2.41
13.	Allotting time for thinking in the class	2.34
14.	Asking students to state the difficulties they encountered and explain how they resolved them	2.23
15.	Discussions with students regarding the thinking strategies used in class, such as making decisions, asking questions	2.38
16.	Creating situations whereby the students present contradicting positions and try to convince one other	1.76
17.	Encouraging students to participate in scientific contests and	1.52

	projects	
18.	Guiding students to present diverse viewpoints around a particular issue	1.33
19.	Asking students to formulate their own questions	1.45
20.	Learning through teamwork in the class	1.42
	*(0 – never, 1– seldom 2 – often, 3 – very often)	

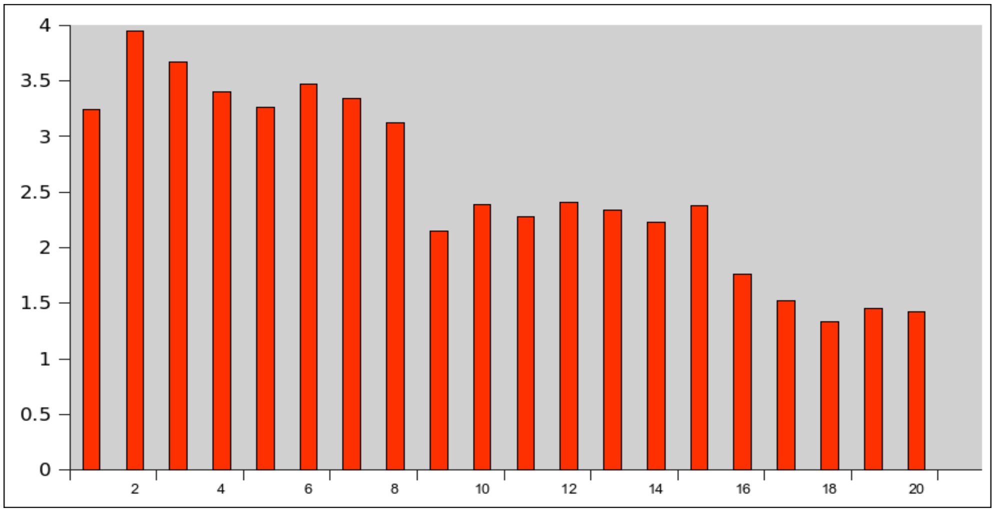

Figure 1: A four-stage model of instructional strategies aimed at fostering thinkingskills into teaching subject matter.

TEACHERS' ARGUMENTS FOR MAINTAINING CONSERVATIVE TEACHING

While teachers' explanations as to how or why they use a specific teaching strategy refer mainly toeducational practices, the reasons they give for maintaining conventional teaching give us a very goodidea about their perceptions of reform-based science education. Beyond the common claims that the obligation to convey mandatory content does not allow enough time for more progressive instruction, theteachers mentioned other reasons for continuing to use traditional teaching. Two interviewees perceived the development of thinking as an issue separate from the teaching of biology, and suggested providing students with special courses to foster thinking skills. One teacher said the following:

"It is necessary to include the learning of logic in the curriculum. This is important."

Other teachers believed that the mere teaching of biology develops students' thinking, as the following quotes show:

"Nothing develops thinking like biology, for example graphs, his is abstract thinking, it requires concentration… solving problems…understanding concepts like energy conversion."

Or: "It's easier to develop thinking in biology because you have the tools to do so. What are the tools of thinking? You have a collection of principles and rule… you use them to solve a problem or a conflict… therefore this discipline,biology, helps to develop thinking." Since, as we have already mentioned, biology is commonly regarded as a difficult subject, when teachers in the current study talked about fostering thinking by teaching the subject matter,they probably took into account students havingrelatively strong scholastic backgrounds.Another argument used by the teachers in theirpreference for conventional teaching was that theintensive delivery of subject matter is necessary in orderto control the class:

"In today's situation, if you stop teachingyou lose control over the class, the studentsstart talking."Or:"If I had a quiet class I could hold morediscussions. In our school, discipline is aproblem. In a class that has discipline problems,all you can do is to teach technically."

And also:"Since the students lack the culture ofdiscussion, it is difficult. They start shouting atone another and so it is a waste of time."Three teachers specifically stated that they feltinsecure in using compound instructional strategies, asillustrated below:

"I don't like discussions… I don't knowwhere they lead and I don't have the tools to dealwith this later. In discussions, they the studentssometimes exaggerate, so then what do I do?"

TEACHERS' BELIEFS ABOUT STUDENTS' ABILITIES IN ACQUIRING HIGHER-ORDER THINKING

Certainly, teachers' beliefs about students'understanding, thinking and learning are critical factorsin any educational reform.The conversations with the teachers indicated that theinterviewees were divided into two extreme polesregarding their estimation of students' potential toacquire higher-order thinking. At one pole were four'pessimistic' teachers who said things like:

"In the tests, I wish they knew at leastoneway to solve a problem, my poor students."And "Man was born the way he was… maybe it ispossible to teach him to think a little bit but nottoo much. A creature that was born to crawl willnot be able to fly. It is possible to improve, but ifyou study physics you must know how to boththink and sit."

At the other pole were five teachers who had greatconfidence in their students, as expressed in theexamples below:

“If you keep telling them ‘you have to decide,’‘you decide for yourselves,’ they get used to thenotion that they also have a say in class.”And also:“They are more intelligent than I am, butperhaps lazier; I always say that ‘if I had theirbrains I would have gone a lot farther’.”

The optimistic teachers frequently talk about thepotential of their students to succeed but at the sametime mention their own duty to support and encouragethem. Since students majoring in biology are usuallyselected carefully in each school, the large gaps found inteachers’ viewpoints about the students cannot referexclusively to the students’ scholastic backgrounds butmust also deal with the teachers’ beliefs. We will discussthis point in more detail later in the paper.

SUMMARY

This study aimed at exploring the practices and beliefs that biology teachers have about introducing reform-based instruction into their class. Although all the participants in this study were experienced teachers, and the fact that biology is considered to be a well developed field in R. Macedonia schools, extensive differences have been identified among the teachers in issues such as the use of rich instructional strategies in the class, their self-confidence in utilizing progressive instruction, and their beliefs about their students’ abilities to develop higher-order thinking.

Therefore, despite the fact that the constructivist view of learning has been placed at the center of teachers’ pre-service and in-service programs for at least two decades, teachers often regard reform based instruction as an idealistic view of education rather than a clear schooling practice. The significant diversity of the teachers, as well as the cases in which the teachers highly evaluate their students but show moderate or low self-confidence in their own abilities to teach higher-order thinking, indicate that many teachers are confused or embarrassed about reform-based instruction. Further work is therefore required in teachers’ pre-service and in-service training to make the fostering of higher-order thinking a common ingredient in science teaching.

We summarize this paper by noting two examples of approaches to foster thinking in the science class to emphasize that the notion of reforming science education must be translated into well-defined instructional strategies that teachers can infuse into teaching the common curriculum.

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