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Mathematics and Science Teachers' Concept of Critical Thinking

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Abstract. The need to teach higher order thinking skills is not of recent origin. Educators have been calling for renewed interest in critical thinking for a number of years. Critical thinking is purposeful, reasoned and goal-directed. It is the kind of thinking involved in solving problems, formulating inferences and making decision. The study was designed to answer some questions related to teachers' conceptions of critical thinking and teaching methods and techniques that promote critical thinking. We used questionnaire as a research instrument to obtain data for this study. Questions were focused on drawing out teachers' perceptions on critical thinking. Quantitative and qualitative analysis of questionnaire reveal that math and science teachers are not familiar with the concept of critical thinking. They did not seem to understand the requirements needed to develop students' critical thinking abilities and skills. Only a few teachers who took part in this research use teaching methods and techniques that develop critical thinking. The dominant teaching approach was lecturing. If we want to introduce and develop students' critical thinking, teachers need to understand the nature of this complex concept, and then be willing to include it into the classroom. The results lead to a conclusion that the teachers do not think critically, apart from the fact that they do not know what critical thinking is. In order to understand the nature of critical thinking, math and science teachers must start asking themselves the fundamental questions about the nature of knowledge, methods and techniques of teaching, learning styles and the process of thinking. That will be the starting point for establishing teachers' conception of critical thinking that is necessary for developing students' ability to think critically.

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1 Introduction

By nature, education is inertial and conservative system. Education reform is never easy, but education reform is necessary, and now more than ever. Many concerns about math and science education are at an international level. These

concerns are becoming especially focused and rising to a level of Ministry of education, Government, Congress or Assembly. Twenty years ago, a report of Carnegie Commission stated that the situation about the science education is "a chronic and serious threat" to the future [1].

It is generally recognized that our students need to acquire skills necessary to succeed in the 21st century workplace. Our ever-changing and challenging world requires students, our citizens, to go beyond the building of their knowledge capacity; they need to develop their higher-order thinking skills, such as critical system thinking, decision making, and problem solving [2].

The purpose of this paper is to examine math and science teachers' perception of critical thinking (CT). It is attempt to answer some questions about disposition toward CT, definition of the concept of CT and teaching and learning methods and techniques suitable for CT.

2 Critical Thinking

For many researchers and educators there is no more central issue to education than thinking and reasoning. The need to teach higher order thinking skills is not of recent origin [3]. According to Zoller [4], cognitive skills fall under two categories: LOCS (Lower-Order Cognitive Skills) and HOCS (Higher-Order Cognitive Skills). It is commonly accepted that memorization and recall are LOCS that require only a minimum level of understanding, whereas the application of knowledge and CT are HOCS that require deep conceptual understanding. As an example of HOCS, CT is a complex cognitive process that requires higher level of skills during intellectual activity. The exact meaning of the term CT has been the subject of much academic debate in a variety of educational contexts [5].

Literature provides a wide range of definition for the term CT. Many definitions of CT are quite different and depend on an individual understanding and research needs. Halpern [6] defines CT as purposeful, reasoned, and goal-directed thinking. It is kind of thinking involved in solving problems, formulating inferences, calculating likelihoods, and making decisions. Another definition [7] states, CT is a cognitive process that involves higher level skills such as interpretation, analysis, evaluation, inferences, explanation, and self-regulation.

Although there is no universally accepted singular definition of CT as definitive and complete, there appears to be some agreement and coherent view about what the term refers to when we use in literature. In other words, it is easier to recognize than to define CT.

3 Methodology

3.1 Participants

This study includes 89 voluntary participants, math and science teachers from seven public secondary schools in the Republic of Macedonia. The study was designed to answer the following questions: How do Macedonian math and science teachers understand the concept of CT? Which teaching methods and techniques they use in order to teach CT? Have math and science teacher ever been involved in CT activity during formal and informal education? Are there a good examples of practice in which teachers adopt instructional strategies developing students' ability to think critically?

3.2 Instrument

As a data-collecting instrument for the study, we used teacher questionnaire. It consists of four sections: Section A (the first six items) consists of six more general questions about subject areas, teachers' experience and teacher formal education, use of computer, Internet and Email. Section B consists of nineteen items, which ask for an opinion from teachers about subject they teach, and their opinion about themselves, their beliefs and persuasion. Section C contains ten Likert type items in the form of statement about the concept of CT, literacy, textbooks, knowledge and thinking. The last Section D contains seven open-ended questions, which ask for an opinion from teachers concerning CT, teaching methods and techniques, CT related to practice and teachers' formal and informal education.

4 Result and Discussion

Teacher characteristics are presented in Table 1. Only few teachers do not have computer or internet access at home and do not use Email. These exceptions refer to teachers with more than 35 years of teaching experience. Additionally,

Table 1. Basic characteristics of selected teachers in Macedonian secondary schools

Subject	Number of teachers (N=89)	Average teach. exper. (years)	Computer at home (Yes)	Internet access (Yes)	e-mail (Yes)
Math	27	15	27	27	25
Physics	26	20	26	26	26
Chemistry	18	16	18	17	17
Biology	18	17	17	17	17

there is no teacher with PhD or master's degree, all of them have bachelor's degree; average teacher experience is 15 to 20 years.

The next results presented in Table 2 are about teachers' disposition toward CT (questions in section B). Teachers are given instructions and an example how to select a box to tick. The text on the left refers to the first two boxes, and the text on the right refers to the last two boxes. The box near to the text is considered to be stronger than another one. The sum of ticked boxes in the same row is not 89 because of unanswered questions. For example, 14 teachers did not answer the last question, likely they do not know what it means conformist.

Table 2. Summarized results for five questions in Section B

Text from left	Ticked box				Text from right
I like challenges	63	21	1	1	I don't like challenges
I like to solve problems, puzzles	58	27	2	0	I don't like to solve problems, puzzles
I make decisions quickly	16	28	15	25	I think over when I make decisions
I come to conclusions quickly and easily	12	23	22	29	I come to conclusions cautiously and carefully
I am a conformist	9	31	20	15	I am not a conformist

In order to probe teachers' understanding of CT we used question about meaning of the term CT in form of Likert type item (Table 3). About 35% of teachers strongly agree or agree with the statement that is sign of confusion about the meaning of the term CT. The second Likert type question is closely related to disposition toward CT. Distribution of answers shows teacher's view about the term literacy. Teachers must distinguish reading, math and science literacy.

Table 3. Likert type items

Statement	Strongly agree	Agree	Disagree	Strongly disagree
To think critically means to take negative attitude and to oppose to one's opinion	5	26	14	43
A literate person means a person who can read, write and perform basic arithmetic operations	15	26	21	26

Results in Table 4 indicate that classroom lecture is the most widely used teaching method. There is almost no possibility lecture format to be use to develop CT. Lecture emphasize rote learning rather than CT, but in all of the other methods and techniques teachers can find at least one way to promote and develop student CT. Additionally, a strong correlation exists between the used methods

Table 4. Teaching methods and techniques

Which teaching and learning methods and techniques do you use in your course?	Frequency	Teaching methods and techniques that are not mentioned
Lecturing	34	Critical reading
Dialogue	22	Content analysis
Demonstration and hands-on activities	20	Discovery learning
Group discussion	18	Poster session
Individual work	15	Concept mapping
Work in group	12	Reformulating the problem
Use of illustrations	10	Role playing
Inquiry based learning	7	Film and video
Experiment	5	Science excursion
Brainstorming	4	Quiz
Project work	4	Essay writing
Use of internet	4	Story telling
Self-assessment	3	Case study
Analysis and synthesis	3	Think-aloud
Debate	3	Verbal reports
Problem solving	3	Highlighting/note taken
Direct teaching	1	Two minute paper
Outdoor lessons	1	

and techniques mentioned in the questionnaire and the perception of CT. Teachers who use dialogue, demonstration and hands-on activities, group discussion, inquiry based learning, debate and problem solving have more clear understanding of the concept of CT. In addition, most of them ticked box (Section B) which is an indicator for good predisposition toward CT.

In addition to the methods and techniques used by the teachers, in the same Table is given the list of ones which are not mentioned in the questionnaires, but popular, suggested by the experts and which have great potential to be related with CT.

Table 5 shows that teachers are individualistic and diverse in their perception about the concept of CT. Some definers here are irrelevant for CT, for example, as a first one with frequency 3. In any case, that cannot be definer for CT. Teachers drawing out this from Likert-type item in Section C. This item we use intentionally as a distractor. We could not find coherent view about the concept of CT in definers used by teachers. Here we must mention the fact that many of the teachers did not answer questions (or any of the questions) in Section D. For example, as an indicator for this are frequencies in Table 5.

Table 5. Critical thinking definers

CT definers mentioned in teachers' answers	Frequency
To take negative attitude and to oppose to one's opinion	3
To be able to see his or her own position from others perspectives	2
How to apply knowledge in new situation	2
To use knowledge in real-life situations	2
The way how to overcame some situation or state	2
The things are not the same as they appear	2
To draw conclusion	1
Objective and fair-minded	1
Not to memorize, to analyze in order to make decision	1
My opinion to some aspect	1
Do not agree to one's attitudes	1
Thinking based on arguments and self analysis	1
To give opinion how to work and solve problems	1
To be critique in finding your mistake, errors, omissions, problems and how to solve it	1
Self-control, to think more creatively	1
To think about problem, where is the problem	1
How to find information, knowledge (critically)	1
Coming to knowledge through Why questions	1

Most of the definers [8] used by experts are presented in Table 6. In this table, they are selected in five groups.

Table 6. Critical thinking definers used by experts

CT definers	Group
problem solving, drawing conclusions, inductive reasoning, hypothesize, convergent thinking, higher order thinking	Scientific reasoning
deductive reasoning, metacognitive skills, Socratic questioning, constructive skepticism, open-minded, rational thinking, evaluating assumptions	Cognitive strategy
adequacy, fairness, objective, logical, accuracy, consistency, precision, responsible	Conscientious judgements
decision-making, synthesis, relevance, clarity, significance, completeness	Relevance
active participation, self-directed, cooperative learning, intellectual challenges, independent thinking, student-centered, discovery learning	Intellectual engagement

5 Conclusion

Taking into consideration the complexity of the concept of CT and literature review obviously it is not easy to define CT and there is not a single definition of CT. Analysis of responses to the questionnaire show that math and science teachers are not familiar with the term CT. A great diversity exists among teachers' understanding of this complex concept. They do not have a clear concept of what it means, but predisposition toward CT seems to be a characteristic of math and science teachers.

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