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# Primary and secondary students' argumentation competence: A case study

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*There is a significant corpus of studies indicating that children even from the age of primary school are capable of providing convenient arguments and that the cultivation of this ability fosters learning significantly. Based on these assumptions, the present paper examines the forms of the arguments that students of primary and middle school use to support their answers. In particular, this study was divided in seven independent activities, where students of a fifth and an eighth grade class had to complete mathematical tasks and support with arguments how they concluded to their answers. We used the simplified Toulmin's argumentation scheme and subsequently, enriched our findings with the argumentation scheme perspective, in order to gain a better understanding of student's reasoning characteristics.*

*Keywords: Toulmin, argumentation, scheme.*

## Introduction

Basic aim of the new teaching methods, starting from the new curriculum in mathematics, which was published by the National Council of Teachers of Mathematics in 1989, is to reinforce reflective thinking and shift from 'learn mathematics' to 'do mathematics'. According to Dewey (1903), children learn effectively through inquiry-based processes, which require from students not only to solve mathematical activities, but also to express their thinking, state their opinion and finally, compare their statements with their classmates'. Thereupon, it can be stated that reasoning organises students' ideas, builds strong conceptual connections and fosters mathematical thinking (Dewey, 1903). Following these assumptions, the cultivation of proper language skills plays a significant role in this thinking process, as it allows students to express accurately their thoughts by forming arguments. Halliday (1993) uses the phrase 'interpersonal gateway' to refer to the power of language as interactive tool in the communication between students and teachers. Regarding our study, we adopted Toulmin's argumentation model in order to explore the reasoning ability of primary and secondary students. Toulmin's model was first used by Krummheuer (1995) in the field of teaching mathematics. According to the latter, claims, data and warrants are not predetermined, but are constructed through the process of classroom discourse and interaction. Toulmin's model can describe the structure of an argument by specifying its components, but it cannot characterize the quality of the particular argument. Therefore, at a second analytical level, we enhanced our analysis by using argumentation scheme theory, used as in Metaxas, Potari, & Zachariades, (2009).

## Theoretical background

According to Schwarz et al. (2003) constructing knowledge is the process of composing evidence in such a way, that the selected claim is supported by provided evidence and further supported related to other co-existing beliefs. Moreover, a plethora of studies have established that argumentation

plays a crucial role in the development of knowledge and scientific reasoning. The same holds in the field of education, either as a means to learn (argue to learn) or as a goal of instruction (learn to argue). Schwarz (2009) describes “learning to argue” as the acquisition of general skills such as justifying, challenging, counterchallenging, or conceding, whereas “arguing to learn” refers to the fulfillment of a certain goal through argumentation in a specific educational framework. In other words, the first path uses argumentation as a goal, while the second one as a tool that contributes to the learning process. In order to analyse students’ argumentation we employed the classical Toulmin’s model and subsequently, the recently developed, argumentation scheme approach.

### **Toulmin’s theory**

Argument structure has been used several times as a tool of analysing public discourse regarding mathematics and their teaching. A significant number of these analysis have been conducted by using Toulmin’s theory. Toulmin (1958) has claimed that the traditional formal logical analysis of arguments is not rich enough to include parts of common arguments such as qualified conclusions, response to other arguments and inferences. He proposed a model for the layout of arguments that consists of six basic parts, each of which plays a different role in an argument (Metaxas, Potari and Zachariades, 2016). The first one to apply Toulmin’s model in mathematics education was Krummheuer (1995). Since then, some researchers have focused on the analysis of mathematical arguments of students, including usage of proof in general (Yackel 2002), number skills (Evens & Houssart 2004), geometry (Pedemonte, 2007) and algebra (Pedemonte 2008). By studying the argument components a student is using when talking about a solution in mathematics, we could have some indication about his/her understanding and generally, his/her perception about mathematics.

### **Argumentation schemes**

Toulmin’s model describes the structure of an argument giving its components, but it does not reveal much about the quality of the particular argument. However, the content of the Warrant and the Backing in an argument should be considered in the evaluation process of an argument. For this reason, we combined Toulmin’s model with the tool of argumentation schemes to analyse the quality of the Warrant and the Backing. For example, a Warrant that is based on the authority of a source (teacher has said so...) is fundamentally different to a Warrant that is based on a mathematical relation or to an intuitive remark. Standard accounts of argumentation schemes describe them as the representation of different types of plausible arguments that, when successfully deployed, create presumptions in favor of their conclusions (Metaxas, Potari and Zachariades, 2016). Argumentation schemes have been assigned a role in the analytical reconstruction of an argument, as well as its evaluation. In reconstruction, these schemes can be used to identify and categorise certain patterns of reasoning, contributing to the identification of implicit claims of the arguer. Moreover, a set of critical questions are associated with each argumentation scheme to be used in the evaluation of arguments and their correspondence with each category (Walton, Reed & Macagno 2008). Another significant aspect of argumentation schemes is that the evaluation of the argument is directly associated to the dialogue as a whole, rather than evaluating it independently and isolated from the context that is being constructed. Consequently, every argument will be evaluated via the critical questions, in the context of the dialogue of which it is a part of. Thus, critical questions are a kind of evaluative points, providing a list of individually necessary

conditions for the success of particular schematic arguments. For instance, an argument can be characterized as weak if it fails to answer appropriate critical questions that have been or might be asked in a dialogue (Walton, 2006). In addition, an argumentation scheme could inform us about the quality of a warrant or a backing as a form of an argument (Metaxas, Potari and Zachariades, 2016).

### **The structure of the course**

The theoretical underpinnings for looking at the classroom discourse was the theory of symbolic interactionism. Individuals are seen to develop personal meanings as they participate in the ongoing negotiation of classroom norms (Cobb, 1999). The centrality given to the process of interpretation in interaction is one of its main principles (Blumer 1969). While individuals are interacting with each other, they have to interpret what the other one is doing or is about to do. Each person's actions are formed, in part, as he/she changes, abandons, retains, or revises his/her plans based on the others actions (Cobb, 1999). Moreover, the group discussions can provide participants with learning opportunities by turning their implicit supporting arguments into explicit. In addition, the objects of debate can result in a change of their status and engage them at a higher level of mathematical reasoning. The very act of argumentation could produce learning on the part of the arguer (Jermann and Dillenbourg, 2003). In our study, the materials used to trigger the discussion were tasks, which were based on topics that research and experience have highlighted as important.

### **Data analysis**

In order to study the ability of elementary students to reason in mathematics, we implemented a series of activities, where the students of a fifth and an eighth grade classroom in Greece were asked to solve mathematical exercises and in addition, to provide with written arguments why they believe their answers were correct. Having analyzed all the written answers following the methodology of previous studies (McNeill, 2011), we drew the conclusion that students of that age have the ability to form arguments in order to support their solutions. More specifically, 66% of the students who provided some kind of argumentation, used to some extent the simplified Toulmin's argumentation scheme, which is consisted of three parts; claim, data and warrant. Although not all answers had all three essential parts, they could be adjusted to Toulmin's pattern arguments. Toulmin's model allows students to reason in a completed way, which presents the hypothesis, the explanation and the solving process. Subsequently, the arguments that followed Toulmin's model were analyzed according to their structure following the analysis of other relevant studies (Evagorou and Osborne, 2013) that have taken place in the past and adopted the modified version of Toulmin's Argumentation Pattern (Erduran et al., 2004). Out of the 66% that is mentioned above, nearly half of the students (Table 1) included all three essential parts, that is they were able to state their opinion (claim), provide all the necessary support (data) and finally, connect them in a sufficient way (warrant). This completed structure is followed by the students who managed to include the claim and the data to their answers, but weren't able to provide effective warrant (33.4%). Finally, a little less than 20% wrote only their opinion, without justifying or explaining how the concluded to this claim. There is a similar pattern in secondary school students, where there is only a slight differentiation around 2-3% in the first two columns.

Reasoning forms of Toulmin's Model			
	Claim – Data - Warrant	Claim – Data	Claim
Primary school	47.6%	33.4%	19%
Secondary school	45.2%	36.2%	18.6%

**Table 1: Reasoning structure of Toulmin's Model**

The following table presents an example of each category, taken from an activity that students had to form the biggest decimal number by throwing a dice and placing the digit in a suitable place.

Claim only	<i>I have to place the numbers with greater value in tenths etc.</i>
Claim-Data	<i>If I get 6, I'll place it in tenths because 6 is the biggest number I can get. If I get 1, I'll place it in thousands because is the smallest number I can get.</i>
Claim-Data-Warrant	<i>In order to win the game I have to make the biggest number. I need to place the bigger numbers in the integer part and the smaller ones in the decimal part. So, the best thing I can do is to place the numbers from the biggest to the smallest.</i>

**Table 2: Excerpts from each category**

Having completed the primary data analysis, we studied the produced arguments using the argumentation scheme theory, which helped us gain insight regarding the quality of the argumentation used.

## Discussion

Having analyzed the data and in correlation with previous related studies, it can be clearly said that elementary students can form arguments in order to justify their mathematical thinking and that the most common way to state their reasoning is by using Toulmin's Argumentation Pattern (TAP). However, students of that age do not recognize the significant role of proof and therefore, they don't understand that justification of their thinking is essential. Even though they solved the exercises correctly and they presented the important data, they don't define clearly the connection between data and claim, which according to TAP is known as warrant. This deficiency must not be understood as lack of students' ability, as in many of their answers and especially when is asked by the teacher they expand their reasoning and include the semantic warrant. The obvious implication that follows the existence of a correct claim and a written data could be the reason the students don't regard as necessary to include a warrant in their answers. Consequently, this identification and evaluation of the missing premises or conclusions could be greatly enhanced by the employment of

the argumentation scheme theory (Walton, Reed & Macagno, 2008), where most of the arguments are considered forms of plausible reasoning that do not fit into the traditional deductive and inductive argument forms. In this case, a further analysis is needed in order to evaluate the content of the argument accurately. For example, the absence of the warrant or backing is due to people's belief that these are automatically entailed from the data given and there is no need for further justification. This deficient form of argumentation can be enriched and expanded in order for an argument to acquire the desirable structure. Likewise, short answers that were given by the students and were characterized by lack of structure, were in fact complete, if the essential parts that were considered obvious and were implied, are included so as to form a complete argument. Below there are given two examples of arguments that were at first deficient, but after expanding them, they transformed in complete arguments according to TAP. The first example is taken from an activity, where students had to form the biggest possible decimal number, using the digits that were given after rolling a dice six times.

*Student: I will win by putting the number to the correct places. For example, if I get number 1 I will place it in the thousandths.*

The above argument is considered short and deficient. However, it is clear that the student has understood the procedure in order to form the biggest number, but still prefers not to include all the essential information to his answer, as he believes that it is obvious. He argues by employing an argumentation scheme of illustration, which nevertheless remains without support. Nonetheless, after the teacher's claim, the student added the hidden parts in order to transform his deficient answer to a complete argument. We give a reconstruction of the argument:

*Student: I will win by putting the number to the correct places [claim]. I have to place the small numbers in the decimals' places (tenths, hundredths, thousandths) and the bigger ones in the integer part of the number (tens, hundreds, thousands), because decimals have smaller value than integers [warrant]. For example, if I get number 1 I will place it in the thousandths [claim], because number 1 is the smallest I can get and thousandths have the lower possible value compared to the other places [warrant].*

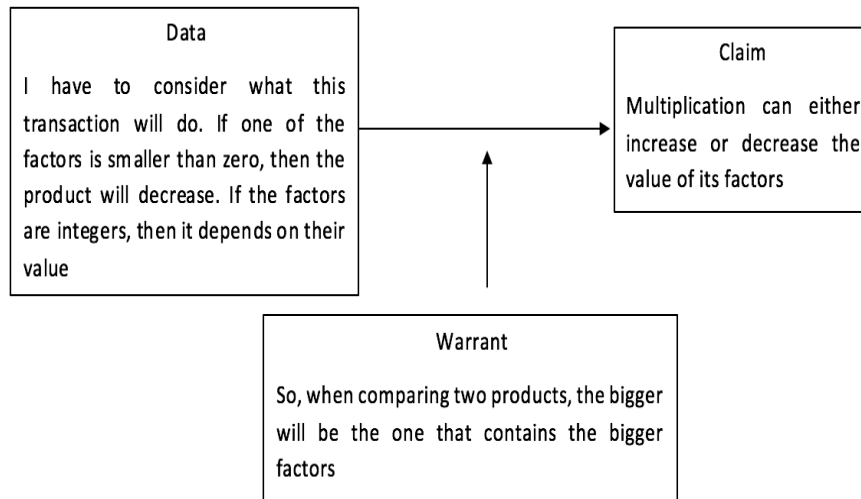
In analyzing student's elaboration of his argument, we can either consider the second argument as a continuation of the first one, in the sense of using the previous claim as the data of the second argument, or we could interpret the whole second syllogism as a backing of the first one. In any case, the scheme employed in the second argument is, again, a scheme from illustration but now connected to the previous scheme from established rule (I have to place ...integers). As a result, regarding the quality of the schemes employed, the student actually elaborates his reasoning by using an established rule, which again is supported by a scheme from illustration.

The second example is taken from an activity, where students were asked to estimate the product of a decimals' multiplication without making the transaction, by simply observing the factors.

*Student: I have to consider what the multiplication does; if it makes the number bigger or smaller.*

The above claim contains the perception that multiplication can either grow or reduce the value of its factors. Even though he misses many essential parts, if the claim is expanded, we can take an efficient answer. A reconstruction of the above statement could be the following:

*Student: Multiplication can either increase or decrease the value of its factors [claim], so I have to consider what this transaction will do. If one of the factors is smaller than zero, then the product will decrease. If the factors are integers, then it depends on their value [data]. So, when comparing two products, the bigger will be the one that contains the bigger factors [warrant].*



**Table 3 - Analysis of student's extended argument**

Again, taking into consideration the schemes employed, we could note the presence of a scheme from (positive) consequences (Walton, Reed & Macagno, 2008). The (implied) fact that in order to answer the posed question, we should consider the effect of the multiplication on the magnitude of the numbers, is a scheme from consequences. The explanation that follows is the elaboration of the scheme; the consequences in each case. The student explains in a more abstract (mathematical) way his reasoning, which is in a clear contrast to the previous excerpt (where the invocation of an illustration was employed).

Our thesis is that elementary students are capable of forming arguments and reasoning in mathematics, but one of the main characteristics of that age is the short way they express their arguments and therefore the absence of basic parts. The deficient character that defines most of the arguments can lead to the conclusion that all students reason according to TAP, but the structure is incomplete, as some parts are considered obvious and children believe are excessive. Additionally, another interesting point is the insignificant difference between the two grades, especially if considered that students from the seventh grade start using and structuring their first proofs. Nevertheless, by taking into account the types of the syllogisms employed, in the sense of argumentation schemes, we could shed a bit more light into the quality of arguments used. In the primary school case, students used mainly schemes from illustration and from consequences, which probably is due to the students' inadequate exposure to mathematical thinking or argumentation structuring in general. On the other hand, the eighth grade students employed more schemes from rules to cases, which accounts to their better understanding of the structure and function of a proof. As a result, although the Toulmin model is indicative of the structure of the arguments students use, it is not enough to discern the difference of the quality of their arguments. This could be easily overruled by using argumentation schemes. Finally, it should be noted that justification and correctness should be distinguished in the analysis of an argument. For example, a premise that is

based on an authoritative opinion or is justified by intuition or a meme could be turn out to be false. Consequently, representational tools as the argumentation schemes that could exhibit the implicit structures of arguments can enhance the reconstruction and comprehension of the syllogism. In further studies it would be interesting to examine ways that will cultivate the argumentative way of thinking and grow the ability to express completed arguments that contain all essential parts.

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