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THE USE OF GRAPHS AND DIAGRAMS IN EDUCATION

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Abstract:
Graphs and diagrams as visual aids can enhance a lesson and improve the learning process. This study examines the views of secondary-school teachers on the use of these tools when teaching lessons and how they can contribute towards the success of the lessons. The findings showed that graphs and diagrams are not used as much as they should be by teachers, who often resort to using other visual aids. This is both due to a lack of training on the part of the teachers, but also because many schools are not equipped with the technological resources to facilitate the planning and use of these aids during the lessons.

Keywords: graph, diagram, teaching aids, visual teaching aids, visual illustrations, visual representations

1. Introduction

The term "graph" means a mathematical or combinatorial object which is represented by images and can be depicted simply and easily (Manolopoulos *et al.*, 2014). A graph or a chart is the easiest way in the discipline of Mathematics to represent and describe interconnected information (Kolountzakis & Papachristodoulos, 2015).

Historically, graphs are first believed to have appeared in the 18th century when Leonard Euler, a Swiss mathematician, drew a graph to solve the problem of the 7 bridges of Konigsberg. Basically, the inhabitants had been competing with one another as to who could start off from a particular land point in the city and cross the 7 bridges joining up the two sides of the city and then end up at the point where they had started. In 1736, Leonard Euler solved this problem by drawing a layout with nodes and vertices, thereby forming a graph. Basically, what Leonard Euler did, thereby capturing the interest of the

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scientific community, was to illustrate in a simple and natural way the relationships between objects. It has been demonstrated since then that representing objects and relationships pictorially can be useful for analysing and tackling various problems (Hartmann & Weigt, 2005).

The term "diagram" means a simplified presentation of statistical data, constructs and concepts used in many human activities to present and simplify data and information. More specifically, a "diagram" can be considered as being a geometric figure or a graphic representation which helps to enhance the teaching activity, so that the subject being taught can be processed and understood. Diagrams are simplified graphic representations which are used to visually organise information and to present ideas. In the field of education, using graphs and diagrams can help teachers enhance their teaching content and contribute to the learning process. This is of particular benefit for pupils, who thereby benefit more thoroughly from the new knowledge (Fathulla & Basden, 2007). Graphs and diagrams come under the category of visual representations, these being one of the many categories of visual teaching aids.

2. Research methodology

The aim of this survey was to study the views of secondary-school teachers on the use of graphs and diagrams in education., In particular, an attempt has been made to examine the frequency with which these tools have been included in lessons, the advantages and disadvantages of their use, the results teachers hope to achieve by their use, and, finally, whether they feel that they have been adequately trained to use these tools effectively.

In order to best achieve this aim, it was decided to carry out a qualitative inquiry (Creswell & Poth, 2016). It should be pointed out that from the outset, it was considered important to give special consideration to the views of each teacher because this would help to give a full outline of the subject. Semi-structured interviews were chosen as the technique for collecting the research material (Bryman, 2017), because this is a common research method when conducting qualitative research (Josifides, 2008, Cohen *et al.*, 2011), and offers the chance to evaluate the data accruing from it, not just after this has been collected, but throughout the whole process, thereby gaining a more comprehensive understanding of the views of the participants (Denzin & Lincoln, 2003).

The research data was collected in the spring of 2022. The research material consisted of eleven (11) transcribed interviews with secondary-school teachers, six (6) men and five (5) women, teaching Mathematics, Economics, IT and Natural Sciences, who were working at the time in state schools in the Regional Unit of Xanthi. The purposive sampling method was opted for as the method for the sampling because these individuals, with their experience and their knowledge, well served the aims of the survey (Isari & Pourkos, 2015).

The interviews were conducted separately in order to allow the interviewees to express their opinions freely and in an unhindered way (Cohen *et al.*, 2011). The aim of each interview was to collect data strongly characterised by individual experiences and personal attitudes, so that the teachers' opinions and views could be interpreted better

(Mason, 2009). The ethical nature of the survey was safeguarded by assuring that the data from the participants would be kept confidential and that each participant's individuality, personality and opinions would be respected in full (Robson, 2010). The teachers were receptive and willing to take part in the survey, considering it as being a matter which directly interested them since, through the resulting findings, they could improve the effectiveness of their teaching. Once the interviews had been carried out, descriptive transcripts were made of everything the interviewees had said, excerpts of which are given below.

3. Presentation of the findings

The teachers were asked in the first question to describe how often they used graphs and diagrams when teaching their lessons. The analysis of the research material showed that most of them often use these visual aids, and they stated the following: T2: *"I often use diagrams in Physics lessons"*. T5: *"I often make graphs and diagrams in Mathematics and Physics lessons"*. T6: *"Yes, as often as possible. I think they are essential in every lesson, regardless of the subject. Any lesson without visual aids doesn't come across as interesting for the students, only enhanced lesson do that"*. T7: *"I use graphs and diagrams in any lesson to do with economics because they make my lessons easier to teach"*. T8: *"Yes, in both Mathematics and Physics"*. T9: *"I use them quite often to visually represent data"*. T10: *"Personally, yes, both graphs and diagrams very often. I think that they have a special place in a lesson and should be used in all the lessons"*. T11: *"In my opinion, there is no way you can teach Mathematics, especially in High School, without any graphs and diagrams. But I think that they are also useful and helpful in Language lessons too"*.

Three teachers stated that they do not often use graphs and diagrams in their lessons, because they think that the contribution they make is limited. In fact, they pointed out that whenever they had included them, the pupils had not been helped by them, in spite of the explanations that were given to them. In their responses, they stated as follows: T1: *"I rarely use them; they are hard for the pupils to understand. On the few occasions when I've used them, I don't think they've been very effective"*. T3: *"I hardly use them at all; they don't deliver as expected. Pupils can't easily understand what they are seeing. It takes a lot of explaining for them to be able to understand what is being shown"*. T4: *"Minimal use because the pupils are not familiar with them and they cannot easily understand the data being represented"*.

Following on from the previous question, the teachers who took part in the survey were asked to say what the main advantages of using graphs and diagrams in the educational process were. In their responses, they emphasised: the fact that information is being visualised, that data is being provided visually in a way which can easily be seen, that the lesson flows in a versatile way, that the subject matter can be understood and assimilated more easily, and, finally, that the pupils acquire new knowledge and skills. More specifically, they said the following in their statements: T1: *"Increased pupil interest, the lesson flows in a flexible way, less teaching time needed, concepts and data can be displayed in a simple way"*. T2: *"They help students to understand the subject. We harness the power of images to visually present, in a more concrete way, concepts which are difficult to understand, to bring*

some order to the pupils' minds so that they can familiarise themselves with new information and data". T3: *"We use graphs and diagrams to represent physical quantities. Visual representations help in making a theory understandable".* T4: *"Presenting a concept in a visual way can greatly enhance the learning process. After all, students like to be shown whatever is being discussed in the lesson because they are thereby helped with the large volume of information, and the lesson can be over in a shorter period of time. In addition, the pupils themselves pay more attention, show more interest, and the atmosphere in the classroom becomes more enjoyable and fun".* T5: *"Using graphs and diagrams gives pupils the chance to get involved in the learning process and interact with their classmates. Whenever I use audiovisual material connected with what is being taught, the pupils show a keen interest, pay more attention, and the lesson becomes more enjoyable".* T6: *"I think that the main advantages are the visualisation of the information and the quick assimilation of the subjects being taught. But the pupils also show an interest in the lesson, because they are being given enjoyable stimuli, which are not boring and which attract their attention".* T7: *"The main advantage is the visual information. Pupils get the chance to understand and assimilate the subjects being taught".* T8: *"Graphs and diagrams make the content of a concept clearer. Visual representations of unfamiliar or abstract topics encourage pupils to express their opinions and acquire knowledge and skills".* T9: *"They provide visual information and facilitate the understanding and assimilation of new knowledge. Pupils can grasp complex concepts much more easily and have a better understanding of what is actually being taught".* T10: *"They reinforce the learning, the pupils participate actively in the learning process, and their interest can be maintained at a high level. They provide an understanding of quantities, give a better flow to the lesson, and, through the discussion, enhance communication, interaction and collaboration amongst themselves".* T11: *"They emphasise sometimes certain points and sometimes the overall image of a phenomenon or an activity, they introduce statistical concepts and help pupils to understand the importance of the statistical processing of data".*

The use of graphs and diagrams was not considered to be a panacea by the teachers taking part in the survey. They also pointed out in their responses the disadvantages arising when using graphs and diagrams in a lesson, something to which particular attention and weight should be given. Primarily, they mentioned on the one hand how difficult it was to understand their content when the illustration was not clear and unambiguous and on the other hand, the pupils' lack of familiarity with them. In excerpts from their responses, we can see the following: T1: *"The pupils are not familiar with these kinds of tools; they cannot comprehend and understand things".* T3: *"Their use should be avoided when pupils are unaware and cannot read the information being presented".* T6: *"When there are abstract concepts, there is a risk of pupils getting the concepts mixed up and drawing the wrong conclusions".* T7: *"If they are not clear and easy to understand, they might lead to the wrong conclusions".* T8: *"They shouldn't be used if they don't tie in with the desired outcomes of a particular lesson".* T9: *"When a graphic representation is not clear, it can give the wrong impression".* T10: *"There's no guarantee that the required comparisons to be made, will lead to the outcome that you want".*

Regarding the desired learning objectives envisaged by the teachers through the use of graphs and diagrams in a lesson, these can be briefly defined as: the clarification and understanding of complex concepts, the fullest possible assimilation of new

knowledge and an interdisciplinary approach to the subjects. In particular, they stated the following in their responses: T2: *"Pupils retrieve previous knowledge, extract useful information, achieve better outcomes"*. T5: *"Dealing with the data in a graph or diagram leads to pupils making a deeper study and having a deeper understanding of the steps required for them to draw the proper conclusions"*. T6: *"Experiential activities are given a boost compared with those provided by frontal teaching. Pupils learn to make comparisons and draw conclusions"*. T7: *"A wealth of information is conveyed from a different perspective, but this makes it easier to acquire new knowledge"*. T8: *"They contribute to there being a multifaceted study of a topic, which could involve many subjects"*. T9: *"It is a tool which helps you to approach a concept or a phenomenon from various angles"*. T10: *"The pupils do not learn things by heart but handle the new information in a creative way"*. T11: *"They can be used to support new knowledge or clarify a cognitive confusion. For example, if some pupils have a misconception about a phenomenon, a graph or a diagram can help them to grasp the reality"*.

One focus to which particular weight is given, is to investigate the actions a teacher should take in order to make an effective use of graphs and diagrams in a lesson. Those taking part in the survey suggested studying and processing in advance the material being shown, looking for new ideas for the targeted creation of graphs and diagrams and, lastly, using ICT for a joint attempt with the pupils to collect and represent data. They reported the following in their responses: T2: *"You should look for new ideas, explore new ways to achieve the learning goals either through the internet or through personal training"*. T4: *"Use software which can create graphs and diagrams, with proper preparation and practice at home"*. T5: *"Having enough knowledge, enough personal time available, and, above all, sufficient IT infrastructure… these are, in my opinion, the basic things required for a teacher to use graphs and diagrams in teaching"*. T6: *"With the right guidance pupils should be able to find ways to collect, analyse and reformulate information"*. T7: *"The teaching should be enhanced using technology so that experiential activities can be carried out"*. T8: *"Teachers should be able to personalise the lessons, create experiences for each pupil individually, look things up on the internet, adopt alternative teaching ideas, have discussions with their colleagues and keep abreast of what is new in the field of education"*. T9: *"I have to do the preparation and the planning at home. I don't improvise during the lesson when I'm teaching"*. T10: *"They themselves should be able to create graphs and diagrams… with the right preparation and research before making them"*. T11: *"Explain what a graph or diagram represents and show it at the right moment"*.

The teachers also mentioned the importance of training, which is the key to the correct use of graphs and diagrams in the educational process. Their responses show the importance of educating and training teachers in how to use these tools effectively. More specifically, they stated the following in their responses: T2: *"In particular, training is the surest way to promote learning. Of course, guidance could be available for the teachers and within the school, in order to tackle demanding and very promising lessons"*. T4: *"In order to bring out the dynamism and effectiveness of these tools, the teachers must be trained. However, this should be done using state resources"*. T5: *"It would be worthwhile to train teachers on courses, either long-term or short-term, which would improve their work. Ongoing training is essential and the effectiveness of the teacher's work is just as important for their personal and professional development"*. T7: *"Teachers need to be educated for them to acquire new knowledge and skills so*

that they can respond better to learners' requirements and to the needs of the times". T8: *"Any training is welcome and should be carried as often as possible. Training programmes are vitally important so that teachers can be helped in these sorts of issues".* T9: *"Training teachers so that they are better prepared for their teaching work".* T10: *"All kinds of training would be welcome for teachers to learn how to use these tools correctly. Also, they should know where, when and how to use them, what they are for and what the pupils are going to gain from them".* T11: *"All the training programs open up new horizons in the learning process".*

One teacher said that, in his opinion, training did not offer anything substantial in this direction, because every training programs he had attended had focused on a different area. He stated, in particular: T6: *"Taking part in training programs doesn't give you this kind of knowledge but shows you how to organise a lesson".*

4. Discussion of the findings – Conclusions

A major limitation meaning that the findings of this survey cannot be generalised was the small size of the sample. Furthermore, the participating teachers came from one specific city, and this creates another limiting factor for not being able to generalise the findings: that of the locality being restricted. Therefore, further research studies will have to be carried out on this subject in order to have a more extensive survey of secondary-school teachers' views on the use of graphs and diagrams when teaching a lesson. Finally, this survey only considers the views of secondary-school teachers and not those of primary-school teachers, with whom a comparative approach could be attempted. Lastly, the views of the pupils, who are the most important pillars in the learning process, have not been taken into consideration. For this reason, this investigation into the effectiveness of the use of graphs and diagrams must be considered as being one-sided.

Regarding the frequency with which graphs and diagrams are used in education, most teachers stated that they use them a lot in their teaching, because they think that they contribute to the learning process. Zefkilis (1989) states that visual media, including graphs and diagrams, help in enriching knowledge and in providing complex information. However, most of the teachers thought that their use was limited to the positive sciences and, in particular, to subjects where numbers and physical or mathematical concepts are predominant. Bednarova *et al.* (2012) state that by using graphs, pupils have a better understanding of numerical relationships, can solve equations with greater ease, and easily apply their knowledge when solving exercises. According to Pospiech *et al.* (2019), it is essential to use graphs and diagrams in the positive sciences, although these often make it difficult for learners to create functions, solve problems or understand their terms. Gates (2017) studied the importance of integrating visual representations into the teaching of the Physical Sciences, Technology, Engineering and Mathematics and pointed out how much they help the pupils in their understanding. He also pointed out that both graphs and diagrams can be used as teaching tools to represent concepts and to carry out tasks and activities.

Referring to the advantages and disadvantages of graphs and diagrams in a lesson, the teachers focused on the visualising of the information, on increasing the pupils'

interest and on making it easier to understand and assimilate new knowledge. According to studies (Psaltopoulos, 1981; Laborde, 2005), the use of graphs and diagrams in a lesson helps in the visual representation of data, making it easier to solve mathematical and geometrical problems. Modern research (Koptsis, 2009) states that the use of these tools not only sparks off the pupils' interest but also results in them maintaining their interest in the subject being taught. In addition to the above, graphs and diagrams give accurate representations of the concepts in each lesson. In fact, it is important to note that it is not uncommon for pupils, due to the inadequacies of the words, to fully understand an issue or a phenomenon through graphs and diagrams. Graphs and diagrams help to activate the children's senses, thereby actively involving them in the learning process. Another advantage provided by them is the fact that pupils tend to retain the representations which have been imprinted on their memories by these images for a long time (Hatzidimou, 2019).

Regarding the disadvantages arising from the use of these tools in a lesson, the main issue to be cited was the pupils' unfamiliarity with the information being provided by them. Of course, when graphs and diagrams are not used correctly, there is a risk of incorrect information being provided, which is detrimental to the learning process (Stacheas, 2002). Consequently, some teachers regard the process of integrating these tools into education with reservations and resistance (Lafatzi, 2005). The result is that the teaching is not enhanced with teaching material, and the lessons become restricted to the tight limits of repetitiveness (Stachteas, 2002). It is worth noting that it is not uncommon for students to decode words from the lessons being taught. However, secondary-school pupils often have difficulty with the data being represented by a graph or diagram (Barclay, 1987). In fact, they often treat graphs and diagrams as pictures, and fail to understand the information denoted by them (Preece, 1983; Linn *et al.*, 1987). There is, of course, a range of pupils who can process the knowledge provided by them, unlike others who do not have this ability (Kruzendorf & Wallace, 2000; Byrnes, 2001; Karanikas *et al.*, 2002).

Using graphs and diagrams when teaching can help to achieve the intended learning objectives, namely: the visual representation of concepts, the consolidation of the subject matter and the adoption of an interdisciplinary approach to the subjects being taught. Research by Kalyga *et al.* (2003), on the role and contribution of graphs and diagrams in lessons has shown that pupils, with the help of these tools, can understand and assimilate much more of the subject matter compared to other times. Also, because vision is the most dominant of all the senses, visualising data helps pupils to retain more of the information which they see than that which they hear (Kafousi & Ntziachristos, 2000). Consequently, visual teaching aids, through the visual representations created, stay for a longer time in the memories of pupils who can recall them more easily and more accurately.

In order to make the best use of graphs and diagrams, teachers must definitely study and process the content of these, and prepare for how they are going to use them in their teaching. The research findings by Matsioris and Mylonas (2016) do, in fact, confirm this view.

Teachers are in favour of training because they think that it is particularly important in order to use graphs and diagrams in the educational process correctly and in the best possible way. In addition, the main suggestion for the use of these tools proposed by all of the teachers interviewed in the survey was for the reskilling and training for teachers, coupled with the upgrading of the IT equipment in the schools. Research by Shields and Behrman (2002) indicates that reskilling and training do enhance the work done by the teachers, with the ultimate aim of improving their performance. Further training for the teaching staff (Taratori, 1995; Taratori, 200; Tzoumakas, 2003) and the use of innovative teaching methods enhance the educational process and provide better learning outcomes for the learners. ICT plays a key role in this training, helping teachers to meet the challenges of today and tomorrow (Bikos, 2006). Stringas and Tsibiris (2019) state that when teachers have been adequately informed about modern teaching methods, they can provide their pupils with the appropriate skills. Research by Zieger and Tan (2012) confirms that ICT-trained teachers can provide their pupils with a better-quality education. In addition, a study by Kotsikis (2003) states that teachers receiving further training consolidate their existing knowledge and skills and improve their teaching practices. The need to train teachers and constantly keep them updated on the use of visual tools in teaching has also been suggested in other studies (Tzimogiannis & Komis, 2004; Siorenta & Cohen, 2006; Glazer, 2011, Matsiori & Mylonas, 2016) with a similar subject. The issue of providing training for the teachers has also been highlighted in a study by Stravakou (2002), which states that only by organising and implementing training programmes can schools be able to meet modern educational needs.

Conflict of Interest Statement
The authors declare no conflicts of interest.

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