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Influence of the Illustrations on a STEM Knowledge Diagnostic Test in 4th Grade Primary Education Students

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Abstract

In the current educational framework, the achievement of STEM (Science, Technology, Engineering, Mathematics competencies) in the primary education stage (6-12 years old) is limited by the different teaching methodologies employed by the teacher in the classroom. Several authors point out that scientific subjects require a methodological change focused on newer forms of teaching that promote not only significant learning of concepts, ideas and principles, but also raise interest in science and promote the development of competences. The general objective of this work was to assess the level of STEM knowledge of students in the 4th grade of Primary Education and to analyse the influence of the illustration used in the developed diagnostic tests. In particular, illustrations may be a key tool for developing mental representations that help to remember and relate scientific contents that have been previously studied. The sample consisted of 246 students aged between 9 and 10 from different schools in our regional area. The research design was quasi-experimental with pre-test, control group (CG) and experimental group (EG). As measuring instrument, two 13-item STEM tests were designed, one without illustrations and the other with illustrations. The tests were based on the topics "Matter", "Forces and Energy" and "Machines" taken from several Natural Science textbooks of the chosen level. In both tests, the questions were about the same concepts or presented similar situations, and they were asked in the same order of appearance. The results obtained allowed us, on the one hand, to know the previous ideas and the level of students in relation to STEM competences and, on the other hand, to value visual literacy during the transmission of knowledge and the use of illustrations in the evaluation process. Inferential statistical analysis reveals statistically significant differences (Sig. < 0.05) in the grades obtained in favour of the experimental group. Likewise, it is concluded that supporting scientific teaching with explanatory illustrations of the contents results in a significant improvement in the acquisition of knowledge and its subsequent application in day-to-day situations.

Keywords: *STEM, Primary Education, Science Education, Visual Literacy;*

1. Introduction

Currently, some of the strategies most commonly used in the promotion of effective and lasting learning in the area of science are those related to the research and visualization of reality. The educational process has gradually acquired a methodological and didactic renewal in order to change the old ways of approaching teaching in the classroom. Among the different didactic resources used by teachers in the classroom today we find, for example, conceptual maps, practical activities, technological means, etc. [1]. These resources are an important step forward in the teaching-learning process of science, but not much attention is paid to a particular resource that helps students to learn and relate scientific contents. In concrete terms, we refer to the great usefulness of illustrations in learning certain ideas and concepts, especially in the earliest ages. The youngest population is immersed in a digitized society of images and are experts in accessing, sharing, transforming and communicating images through diverse media [2]. Despite the current availability of the Internet and its related resources, some authors [3] point out that sometimes images are the only reference accessible to students. Thus, in many areas they are considered an essential element, for example, in subjects such as art history (photographs), geography (maps) or drawing. In addition, they are also relevant in science and related subjects such as mathematics (geometry), biology (microscopic observations), geology (maps) or medicine (radiographies). Even knowing the transcendence of the use of the image in the subject matter that concerns us, certain questions arise in relation to its didactic use, which have constituted the bases of this research. *What scientific competences specified in the Curriculum of Extremadura can be developed from basic education? Does image help to remember scientific concepts? Is it convenient to include illustrations as a support in the questions of an exam? What are its benefits and negative*

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consequences? Some of these questions have been answered by previous studies confirming that the use of visual representations produces improvements in learning, reduces the abstraction of scientific concepts, facilitates understanding, improves memory, promotes imagination, introduces scientific phenomena in a way linked to everyday life, facilitates problem solving or motivates students [4].

2. Methodology

The research design was quasi-experimental with pre-test, control group (CG) and experimental group (EG). The general objective of this work was to assess the level of STEM knowledge of students in the 4th grade of Primary Education and to analyse the influence of the illustration used in the developed diagnostic tests. In particular, illustrations may be a key tool for developing mental representations that help to remember and relate scientific contents that have been previously studied.

The sample consisted of 246 students aged between 9 and 10 from different schools in our regional area. These participants were divided into two groups, one control group, made up of 115 students and one experimental group, made up of 131 students. As measuring instrument, two 13-item STEM tests were designed, one without illustrations (CG test) and the other with illustrations (CE test). The tests were based on the topics “Matter”, “Forces and Energy” and “Machines” taken from several Natural Science textbooks of the chosen level. In both tests, the questions were about the same concepts or presented similar situations, and they were asked in the same order of appearance. Questionnaires were randomly distributed among the different courses to eliminate possible interfering variables. For checking the consistency of the questionnaire, the reliability index was calculated, obtaining an appropriate value. Cohen's D and the R Effect Size coefficient were also calculated and the results were adequate as well.

3. Results

The data obtained reveal that STEM capacities in the primary stage do not reach high levels, regardless of the questionnaire carried out. Figure 1 shows the descriptive statistics extracted from each questionnaire. As can be observed in the figure, there are differences in the scores of both groups. The average score obtained by the control group does not reach the minimum passing grade. Students in the experimental group, however, get a slightly higher grade. More specifically, the CG only managed to reach the average passing mark in 5 questions of the total. However, the participants in the EG obtained better scores because on most questions the right answers outweigh the errors. In general terms, we can indicate that the 4th grade students knew certain STEM concepts since they had worked with the tutors in previous weeks. However, the vast majority did not remember them with certainty, so it was evident that no adequate and meaningful memories were created to enable the review of STEM competencies in future situations. Meanwhile, the inclusion of illustrations in the questionnaire has largely led to more satisfactory ratings. The averages in questions 1, 2, 3, 5 and 7 on the contents of *“Forces and energy”* are better in the EG. With regard to the questions related to *“Machines”* (questions 4, 6, 8, 9 and 13) it is clear that the grades have also been higher in the students of the EG. However, on the subject of *“Matter”* (questions 6, 10, 11 and 12), the averages obtained by the GC and the GC do not differ significantly.

Question	Group	N	Mean	Std. Deviation	Std. Error of the Mean	Question	Group	N	Mean	Std. Deviation	Std. Error of the Mean
Average scores	CG	115	0,489	0,187	0,0175	Q7	CG	115	0,287	0,454	0,0423
	EG	131	0,594	0,167	0,0146		EG	131	0,526	0,501	0,0437
Q1	CG	115	0,400	0,492	0,0458	Q8	CG	115	0,469	0,501	0,0467
	EG	131	0,450	0,499	0,0436		EG	131	0,641	0,481	0,0420
Q2	CG	115	0,652	0,478	0,0446	Q9	CG	115	0,539	0,500	0,0466
	EG	131	0,778	0,416	0,0364		EG	131	0,671	0,471	0,0411
Q3	CG	115	0,513	0,502	0,0468	Q10	CG	115	0,373	0,485	0,0453
	EG	131	0,839	0,368	0,0321		EG	131	0,351	0,479	0,0418
Q4	CG	115	0,426	0,496	0,0463	Q11	CG	115	0,791	0,408	0,0380
	EG	131	0,419	0,495	0,0432		EG	131	0,709	0,455	0,0398
Q5	CG	115	0,382	0,488	0,0455	Q12	CG	115	0,678	0,469	0,0437
	EG	131	0,626	0,485	0,0424		EG	131	0,816	0,388	0,0339
Q6	CG	115	0,365	0,483	0,0451	Q13	CG	115	0,443	0,498	0,046
	EG	131	0,351	0,479	0,0418		EG	131	0,542	0,500	0,043

Figure 1. Descriptive statistics of the CG and EG average ratings

The students of the EG show a higher knowledge about STEM competences thanks to the support received by the illustrations. However, they also present misconceptions and in some areas they do not achieve the desired results. It was considered relevant to prove the existence of statistically significant differences between groups by performing a Student's t-test. A value of Sig. < 0.001 was obtained, with a difference of means in favour of the EG in the average scores. In order to verify which questions produced such significant differences and thus analyse the usefulness of the illustration according to the topic of the question, an inferential statistical analysis of questions was carried out, the results of which are shown in Figure 2. As can be seen in Figure 2, the illustrations improve the acquisition and retention of STEM content, as the existence of statistically significant differences in most questions of the EG test against the GC test is verified.

	t	df	Sig. (bilateral)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Average Score	-4,627	244	0,000*	-0,104	0,022	-0,149	-0,060
Q2	-2,216	244	0,028*	-0,126	0,057	-0,238	-0,014
Q3	-5,864	244	0,000*	-0,326	0,055	-0,436	-0,216
Q5	-3,911	244	0,000*	-0,243	0,062	-0,365	-0,120
Q7	-3,910	244	0,000*	-0,239	0,061	-0,360	-0,118
Q8	-2,737	244	0,007*	-0,171	0,062	-0,295	-0,048
Q9	-2,139	244	0,033*	-0,132	0,062	-0,254	-0,010
Q12	-2,533	244	0,012*	-0,138	0,054	-0,246	-0,030

*Figure 2. Student´s t-test between questions (*Sig < 0.05)*

4. Conclusions

With regard to the acquisition of STEM competencies during the early school years, we can say that it would be useful to analyse the methodologies currently used in the classroom with the aim of further deepening the research. It would be interesting to study the knowledge and strategies that the teacher uses when dealing with this scientific content with students, since, as a rule, students tend to forget about it by learning more memoristically. There is therefore a need for models on science teaching and learning to emphasize issues related to motivation and interest in the area.

Based on the results obtained, it can be concluded that students have erroneous prior ideas even after working on the scientific contents in the classroom. Most of the students of the CG, even though having dealt with the blocks of contents in the classroom, obtained low grades compared to the students of the EG. Therefore, we consider relevant the use of illustrations in order to remember and relate STEM concepts and contents. This reinforces our opinion on the need to complement the teaching methodologies that are only limited to the simple provision of content, with the use of visual

resources that allow students to better remember the concepts explained. As a negative aspect, perhaps due to the very approach of the questionnaires, it should be pointed out that the use of illustrations in science is not always appropriate, depending on the subject under study. Their usefulness will need to be further explored in future research. Likewise, it is concluded that supporting scientific teaching with explanatory illustrations of the contents results in a significant improvement in the acquisition of knowledge and its subsequent application in day-to-day situations.
Currently, there is still a need for teachers, transmitters of knowledge, to continually offer students new ways of learning science. As some authors point out [5] it will be necessary to approach innovations from science education in those areas that contribute to students acquiring acceptable levels of science and technology knowledge that they can apply to the real situations that they will encounter in their daily lives, helping them to be scientifically and technologically literate citizens.

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References

[1] Martínez, G., Mateos, M. and Naranjo, F. L. "Design and Validation of a Teaching Sequence Based on Concept Maps to Achieve Meaningful Learning of Science Content in Primary Education." In International Conference on Concept Mapping. Springer International Publishing, 2016, pp. 54-65,
[2] Ruiz, J. M. “El uso de imágenes como recurso didáctico”, España: Edinumen, 2013.
[3] Perales, F. J. “Uso (y abuso) de la imagen en la enseñanza de las ciencias”, Enseñanza de las ciencias, 2006, pp. 13–30.
[4] Otero, M.R. “Investigación en imágenes en la educación en ciencias imágenes, palabras y conversaciones”, IV Encontro Nacional de pesquisa em educação em ciencias, 2003.
[5] Caceres, F., Vilchez, J. and Gonzalez, F. “Los contenidos procedimientales y actitudinales en las diferentes leyes educativas en España. La necesidad de colaboraciones científicos-profesores-estudiantes para conseguir la alfabetización científica”, 27 Encuentros de Didactica de las Ciencias Experimentales, 2016, pp. 667-674.