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ARTIGO ORIGINAL

Science and technology workshops as a pedagogical strategy for teaching science in elementary schools

Oficinas de ciência e tecnologia como estratégia pedagógica para a educação científica de estudantes do ensino fundamental

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Abstract: This study aims to analyze the efficiency of science workshops and thus investigate associated teaching methods used with elementary school students. We evaluated the performance of the 20 participants of a science workshop during the development of 24 science projects in the second half of 2019. Their score was submitted to statistical analysis, which pointed to significant differences throughout the period. We observed that students' performance peaked between the first and the last month of the project. Workshops generate knowledge that, in a spectral and capillary way, is shared with the visitors through the speeches of each participant. Therefore, biased representations and concepts give place to new possibilities of education through research, in a way to fight denialism, which has become entrenched in our society.

Keywords: Elementary school; Scientific education; Teaching through research; Learning technique.

Resumo: Este estudo visa analisar a eficiência de oficinas científicas e, consequentemente, da pedagogia investigativa na aprendizagem de estudantes do ensino fundamental. O desempenho de 20 participantes de oficinas de ciências foi avaliado durante o desenvolvimento de 24 projetos de ciências no segundo semestre de 2019. A pontuação de cada um deles foi submetida a análise estatística para verificar diferenças significativas entre os meses. Observou-se que o desempenho dos estudantes aumentou significativamente entre o primeiro e último mês da oficina. As oficinas geraram conhecimentos que, de forma espectral e capilar, são socializados com outros sujeitos por meio dos discursos dos participantes. Assim, constroem-se novas possibilidades de educar pela pesquisa, enquanto são desconstruídos representações e conceitos enviesados, como aqueles atualmente disseminados pela lógica negacionista que tem se instalado na sociedade.

Palavras-chave: Ensino fundamental; Educação científica; Educação pela pesquisa; Técnica de aprendizagem.

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Introduction

In recent decades, the sociocultural formation of children and adolescents has occurred as result of the rapidly ongoing globalization process and expanded access to information (GIELEN; ROOPNARINE, 2016). Therefore, even though educational models that accompany the new experiences of the subjects are necessary in all levels of teaching, special attention must be given to those involved in Basic Education, when identity formation is more intense (PONTES, 2018). Thus, an educational model that valued the construction of scientific knowledge is of utmost importance as an integrated right to the universal conception of education (KIND; OSBORNE, 2017).

To build new paradigms in education, we need to understand that science and technology are indissociable from contemporary culture (CACHAPUZ; PRAIA; JORGE, 2004). Given the relevance of these components, schools should ignite the spirit of science and offer learning conditions to students at this same level (ARAÚJO, 2006; KIND; OSBORNE, 2017). This philosophy is fundamental to encourage access to information and reflective contact with the world, as well as to phenomena in general, and interactive possibilities of transformation.

Science and technology can also be used for social transformation. In this sense, continuous pedagogical practice is necessary to stimulate students to question social paradigms, to think innovatively, and to use instruments that promote reflection and action when looking for solutions to everyday problems (BOROCHOVICIUS; TORTELLA, 2014). After all, it is imperative to think of technology past to the point that it can transform physical reality, as it can also transform social reality (TRIGUEIRO, 2008).

In this context, Science Education emerges as a transdisciplinary field of knowledge that promotes scientific, artistic, technological, communicational and expressive training for integrational purposes. Its main objective is to involve students in teaching processes so that learning is incorporated as a lifetime need by each one and everyone who integrates these processes (MARANHÃO, 2017). Thus, the importance of Scientific Education lies in providing learning conditions for students to find real possibilities for learning the arts and technologies; incurious and creative interactivity, and influences for their collective and cultural life. The objective of this interactivity is to awaken interest and integrative questioning, i.e., to foster curiosity for important contemporary, historical, and cultural themes.

The use of Science and Technology Workshops is a methodology that is capable of generating excellent results within Science Education (SAN-VALERO *et al*., 2019). It is through them that projects are developed to support student's access to information, knowledge production, and experimental work. Besides that, they are opportunities for teachers to share their own experiences and reflections on the work developed, improving the quality of teaching-learning processes. This text presents the pedagogical and methodological assumptions for the application of Workshops on Science and Technology followed by a case study carried out in Northeast Brazil.

Pedagogical assumptions of the science and technology workshop

Science and Technology Workshops are intended to develop citizenship, to disseminate scientific knowledge, and to lead students and others involved in teaching and learning processes towards intellectual, cognitive, and ethical growth (DIMOPOULOS; KOULAIDIS, 2003). Hence, they can also be understood as learning spaces developed in a pedagogical, dynamic, collective, and intentionally planned manner with the final intent of producing knowledge expanding consciousness, and overcoming of oneself by all participants, as well as the widening of their possibilities of reading the world (OBLINGER; LIPPINCOTT, 2006).

The educational assumptions that guide the use of this type of workshop underline how closely science and technology are related. They instrumentalize and provide resources to the students to develop their ideas and put themselves in the other's place. Students must be able to act deliberately in situations that encourage their argumentation, reflection, and critical awareness, ensuring their involvement in a meaningful learning process and transformative action (BRITO; PURIFICAÇÃO, 2008; DRIJVERS *et al*., 2009; SANTOS, 2005).

Through different pedagogical interventions, students should be stimulated to question the transformations of science, its technological applications, and contributions to their daily life (MARANHÃO, 2017). In this way, the subject learns and takes from this experience the construction of meanings, because he was mobilized in his act of thinking. Besides, he carries with him new questions to interact in other moments of the teaching and learning process and other moments of his cultural and social life.

Within the pedagogical assumptions of the Science and Technology Workshops, scientific education is understood as citizen education (ALVIM, 2012; DIMOPOULOS; KOULAIDIS, 2003; MARANHÃO, 2017) because it promotes a critical reflexive behavior in the learners (DAM; VOLMAN, 2004; PINSKY, 1992; SANTOS, 2017). In this sense, students are also encouraged to value public resources. This leads those involved to rethink the best way to enrich public education.

In workshops, instructors help all students learn by guiding them to use the many tools of 'knowing how to study' and 'knowing how to do' (MARANHÃO, 2017). In his practice, the educator must respect each student’s unique learning style and forgo any types of exclusion from the educational process (TRIGUEIRO, 2008). In this pedagogical idea, the teacher's goal is not to impose values or solutions to socio-scientific problems, but rather to serve as a resource and assist his pupils in choosing, problematizing, and finding cooperative solutions to the issues they encounter on a daily basis.

Furthermore, it is critical to regard teachers as subjects with the right to continuous education (IMBERNÓN, 2010; VARGAS *et al*., 2017). As a result, time and space for teaching formation are required (MARANHÃO, 2017). It is a matter of educating teachers through theoretical subsidies that support their practical reflections in order for them to develop students most consciously and competently (CARVALHO *et al*., 2013).

Finally, the pedagogical proposal of workshops is structured in the current conceptions of the nature of human learning, hence the necessity for active participation of attendees towards the construction of their knowledge, in which their contexts and social reality are also must be taken into consideration (BERBEL, 2011; MARANHÃO, 2017). The main takeaway from this pedagogical process is that developing the ability to use knowledge as a source of data for the creation of new knowledge requires constant inquiry into reality and the application of investigative techniques. Scientific research aids in the development of critical citizens who are conscious of their social responsibilities and are able to contribute to society in a dignified and compassionate way.

Methodological aspects of the science and technology workshops

This section presents methodological guidelines for conducting Science and Technology Workshops based on the methodology used by the Science Education Center of the Maranhão State Institute of Education, Science and Technology (CEC-IEMA), in Brazil.

Science and Technology Workshops deal with real-world problems, tying technology to physics understanding, mathematics as a universal language, history to contextualize the subject, and information technology as a window into global and media challenges. They also strive to develop a link between technology, science and society, producing a dialogue between the person and the world via the use of technological praxis, in which the human becomes the subject, and the world, their object, to intervene and modify their reality through technology.

The workshops last one semester and take place from Monday to Friday during the day shift. Workshops do not substitute for school education, so students register for the shift they are not in school. During the semester, contents that are related to those worked on in Elementary School (**chart 1**). However, differently from what happens in regular education, in workshops, teachers do not limit themselves to presenting content in an expositive way or to carrying out fixation activities, but develop science projects with the students related to each of the subthemes. In these projects, students apply and deepen the theoretical knowledge obtained in regular education, which stimulates the construction of their scientific spirit. The projects developed will be planned at the beginning of each school semester and, therefore, may vary between periods.

Chart 1 – Themes, subthemes, and mathematical contents presented at the Science and Technology Workshops [Source: Maranhão (2017)].

Themes	Subthemes	Mathematical contents
1. Technology and the importance of electricity	• History of Technology; • Social Technologies; • The international system of measures; • Ampere's Law; • Real and conventional sense of the electric current; • Faraday's induction law; • Energy sources and their transformations; • Electric Generators; • How electric power gets to our home; • Conductors and Insulators; • Electric shock and electricity care; • Electrical Circuits (Series and Parallel); • Electrical measurements and the use of the multimeter; • Voltage and electrical resistances (Ohm's Law); • Electric power, consumption and its result in the environment.	• Four operations; • Scale and proportion; • Linear function and its graph.
2. The movements and the thermology	• Heat and temperature; • Applications of thermodynamic knowledge in society; • Position and displacement; • Average and instantaneous speed; • Newton's Laws; • Balance of forces; • The Force of Gravity; • Angular movement; • Rights and duties of pedestrians and non-motorized vehicles.	• Four operations; • Scale and proportion; • Cartesian Plane; • Linear function and its graph; • Vectors; • Pythagorean Theorem.
3. Virtual world and its technologies	• Human, physical and logical part of a computer; • History of Internet; • Dangers on the Internet; • Prejudice in social networks; • Binary Code; • Algorithm.	• Four operations; • Potentiation.
4. Fluids	• A historical view of the study of fluids; • Density and pressure; • Flow of a hydraulic system; • Principle of Pascal; • Hydraulic machines; • Arquimedes and Estevin.	• Four operations; • Scale and proportion; • Cartesian Plane; • Linear function and its graph.

Investigative pedagogy is developed in the workshops, with the main focus being the question. The ideas and studies of philosopher and pedagogue John Dewey inspired investigative pedagogy or research-based teaching (1902-1990).

It promotes discovery-based teaching, project-based learning, questioning, and problem-solving. The characteristics of this type of teaching provide students with a more realistic view of science (ZÔMPERO; LABURÚ, 2011). This teaching style is centered on the problematization of stimulating and challenging daily life events. It is proposed in the classes and activities of an investigative nature to overcome the mere observation of theories that do not favor the student obtaining knowledge, and is dedicated to problematization, which can be solved in laboratory experiments, research in the most varied forms, and/or in a conventional manner (ZANON; FREITAS, 2007).

Investigative pedagogy considers the student as the center of the process, actually involving them in learning, as they need to seek answers to these questions through mastery of the new content taught (VASCONCELOS; ALMEIDA, 2012). In it, the teacher influences the teaching by suggesting problems to be solved, which will generate ideas that, when reflected upon, will make it possible to expand previous knowledge, promote discussions, and establish methods of group work in the classroom, where all opinions are respected and, thus, students can build their knowledge (CARVALHO et al., 2013). In this way, teachers constantly encourage students to ask questions and solve problems so that they experience the question and develop curiosity and the ability to question the nature and objects present in it. For this purpose, the activities developed in the workshop have the following steps (GIL PÉREZ; VALDÉS CASTRO, 1996):

- Presentation of a problem situation at the appropriate level for each class and contextualized, encouraging reflection by students;
- Elaboration of hypotheses;
- Construction of experiments;
- Organization of results in different forms (writing, mathematical graphs, tables, flowcharts, etc.);
- Analysis of the results (hypothesis test), confronting them with the hypotheses, stimulating the students to think in the direction of these hypotheses;
- Socializing the results, discussing them with colleagues;
- Establishing relationships of the contents learned in the workshop in other daily situations;
- Presentation of the final product to the class.

It is important to note that, depending on the project developed, it is not always possible to follow all of these steps, because, as Gil Pérez and Valdés Castro (1996) point out, there is no need to follow them rigidly, as if it were something closed, where the absence of one of the points would jeopardize everything, or where skipping one of the steps would compromise the entire work.

Aim and research question

This quantitative educational study aims to assess the effectiveness of Science and Technology workshops and, as a result, investigative pedagogy (or teaching by research) in elementary school students' learning. As a result, the following research questions guide this study:

- Does the student's performance in science workshops increases over time?
- Is there a significant difference in student performance between the beginning and the end of the science workshops?

Method

Data collection

The data on student performance in the workshops presented in this educational research refers to students enrolled (n=20) in one of the classes (randomly chosen) of the CEC-IEMA in the second semester of 2019 (July-December). Throughout the semester, the teaching team evaluated each student's success in the generated projects using four criteria (**chart 2**). In each of the generated projects, each student earned a score ranging from 0 to 10 for each of the examined criteria (during the data collection period, 24 projects were developed with the subthemes listed in **chart 1**, four per month).

Chart 2 –Criteria used in the evaluation of the students in the second semester of 2019

Criterion	Description
1. Learn to handle instruments, machines, and tools from the workshop	Mastery in the handling of tools and measuring instruments (ruler, multimeter, etc.) by the student autonomously in the construction of cars and miniature houses, electrical circuits, or other activities in the classroom, as well as in the care of them and the surrounding colleagues.
2. Develop logical-mathematical reasoning	The student identifies and solves problems using mathematical operations, unraveling their organization structure, recognizing symbols, and applying calculation logic, as well as reading, interpreting, and constructing graphs.
3. Appropriate the use of the computer and its function	Mastery in the use of the computer in activities, in Internet consultations, in the appropriate use of programs such as text editors, browsers, and compilers, be they written, and/or digital; and in talks and debates about social networks, dangers on the Internet and the socialization of this learning.
4. Learn to relate the ideas of physics involved in the various technological phenomena and transformations of nature and understand the relationships with their daily lives	The student interprets scientific ideas in the use of technologies (mainly electricity and mechanics). During discussions of topics in class, he/she presents arguments formulated with the help of the scientific method and based on scientific studies published in the media. The student sees himself as an agent of transformation of his reality.

Source: Prepared by the authors.

Data analysis

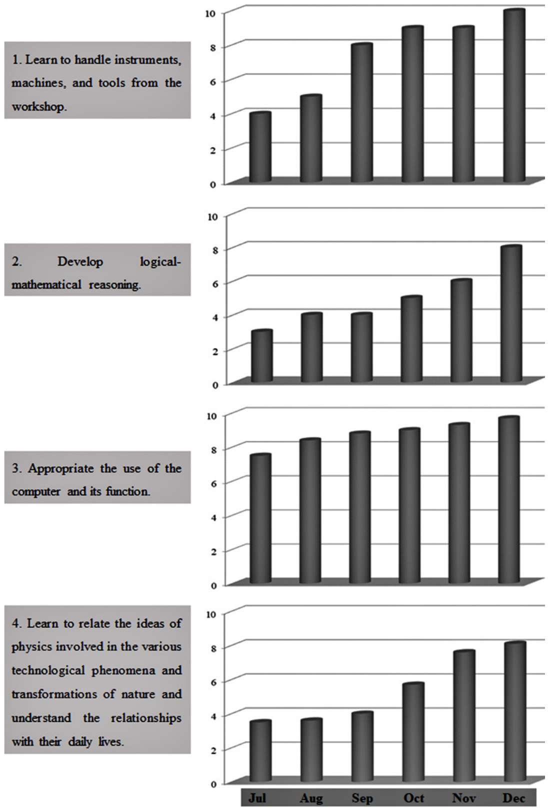
On each criterion, the arithmetic mean of all students' scores was computed. The Shapiro-Wilk normality and Levene homogeneity test. tests were performed on the data. During the data collecting phase, a One Way ANOVA was employed to confirm significant differences in student results. Tukey's post hoc test was employed to determine whether months had statistically significant differences. In all tests, a significance index of 0.05 was assumed. The tests were performed through the aov function in the R statistical software (R CORE TEAM, 2020).

Results

There was a gradual increase in student performance over the second half of 2019. Students showed a low performance at the beginning of the workshop (the month of July), with a more expressive increase, generally, from October, remaining on the rise until December. Criteria two and four were those in which the students had lower performance when compared to others. On the other hand, they have shown good performance in criterion three since the workshop started. As for criterion one, the evolution of student performance followed an upward pattern (**figure 1**).

One-way ANOVA demonstrated highly significant variations in student scores across all evaluated criteria. Tukey's test showed significant differences between the scores in the first months, especially in July, and the last months of the semester, except for criterion four, where July does not differ significantly from any other month. In criterion two, there were still significant differences between November and December. Moreover, in criterion three, the month of July differed from all the others (**table 1**).

Figure 1 – Average student performance against the four evaluation criteria of the CEC-IEMA during the second semester of 2019



Subtitle: Jul: July; Aug: August; Sep: September; Oct: October; Nov: November; Dec: December.
Source: Prepared by the authors.

Table 1 – Results of One Way ANOVA and Tukey's test for the score of students in the second semester of 2019. Only significant values were considered (Source: Prepared by the authors).

			Tukey's test						
Criteria	**F(df)**	**p-value**		**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1. Learn to handle instruments, machines, and tools from the workshop.	$143.3_{(5)}$	4.48^{-46}	**Jul**				5.71^{-05}	2.26^{-05}	7.54^{-12}
			Aug						0.01
			Sep						0.02
2. Develop logical-mathematical reasoning.	$80.48_{(5)}$	9.29^{-36}	**Jul**				4.17^{-05}	0.03	
			Aug				0.03	1.05^{-12}	
			Sep					2.34^{-09}	
			Oct					1.98^{-05}	
			Nov						2.34^{-09}
3. Appropriate the use of the computer and its function.	$16.25_{(5)}$	4.46^{-12}	**Jul**		0.03	0.002	0.0001	2.36^{-06}	3.79^{-03}
			Aug						2.36^{-06}
			Sep						0.0001
			Oct						0.001
			Nov						
4. Learn to relate the ideas of physics involved in the various technological phenomena and transformations of nature and understand the relationships with their daily lives.	$190.9_{(5)}$	1.14^{-05}	**Aug**				9.18^{-14}		
			Sep				1.55^{-12}		

Discussion

The results show that teaching by research, as used in the Science and Technology Workshops, contributes significantly to the students' learning. The difference between the scores demonstrates an increase in the level of knowledge of the students participating in the workshop.

In criteria one, the pupils demonstrated progression. It examined technical and practical factors such as the usage of tools and manual instruments. This type of learning generally includes the learner more powerfully (ANDRADE; MASSABNI, 2011). Besides that, as students get adept at using a tool, the more proficiency they feel every time they reuse it.

Teachers educate students how to utilize various equipment and materials required for the growth of workshops and the generation of scientific knowledge from them. As a result, students learn to gather, choose, order, analyze, question, manage, develop, produce, and apply various forms of data and information required in scientific activity to generate new knowledge (BOROCHOVICIUS; TORTELLA, 2020; TRIGUEIRO, 2008).

Given that they did not get a score of eight or higher, pupils performed less well on criterion two and four than they did on the other criteria. These criteria assessed the student's conceptual understanding, capacity for logical and interpretive reasoning, and ability to apply what was learned to real-world situations. Since these abilities are not encouraged by traditional teaching approaches, which are still used in the majority of Brazilian schools (ALBUQUERQUE *et al*., 2020; OLIVEIRA, 2020), it was anticipated that students would struggle to acquire them.

To break this educational paradigm perpetuated in Brazilian schools, during the teaching-learning process in the workshops, conditions are developed that lead students to learn, express ideas and substantiate them, listen to the ideas of their peers, enunciate them, and seek solutions to problems. To this end, students are taught to appropriate the scientific methodology and technology necessary for the production of scientific knowledge through their participation in the different projects developed in the workshops (MARANHÃO, 2017).

On criterion two, it is emphasized that the role of mathematics in the Science and Technology workshop is to provide means for the formation of logical thinking that permits critical analysis of the role of science in your life. This is because criterion two assesses the development of logical-mathematical reasoning. The student is given the option to consider their own technique of resolution, in which the error is incorporated as a form of learning and motivation in the development of a mathematical citizen of reality, with limitless representations and possibilities, communing collective thought that confronts themes and concretizes logical reasoning in a process that pushes mathematics closer to being more democratic (D'AMBROSIO, 2007).

To understand and use the basic ideas of mathematics in their daily lives is the right of all students, not only those who have more affinity with logical reasoning. Mathematics is present in almost everything, with greater or lesser complexity. To perceive this is to understand the world around you and to be able to act in it (DANTE, 2003).

As for the third criterion, it assumes that humanity lives in an environment transformed by scientific knowledge and its technological products. And this is why scientific education must connect these products to the most basic needs and activities, so that more and more students can comprehend how certain technological options and scientific discoveries can come to influence their own existence (SIAYAH; SETIAWAN, 2020; VENKATESH; MORRIS, 2000). Because digital technologies have become more widely available in recent years, it was expected that students would bring with them basic computer skills, which were expanded during the workshop. The students' prior computer science knowledge aided in the development of projects requiring computer use. Even those who initially struggled with using the tools adapted quickly.

In the Science and Technology workshops, the student is expected to understand that technology is the result of human creation, and thus it should be used responsibly (PITTAS; ADEYEMI, 2019). As a result, the commitment to democratize knowledge, developing students' critical awareness through reading and dialogical discussion of issues, challenges and problems (SANTOS *et al*., 2019).

Criterion four assessed the ability to relate theory and practice through activities centered on daily life, strengthening ties with technologies, and utilizing them to delve into the worlds of Physics, Mathematics, and Informatics, awakening a sense of curiosity, contextualization, and critical thinking. The results obtained in this criterion show how essential it is to expand in the students the capacity of reading, writing, the enunciation of problems, and search for solutions to solve them. In this way, they develop logical reasoning and the capacity of reflection, understanding, and production of scientific knowledge, besides expanding the critical awareness of reality (YORE; TREAGUST, 2006).

Given that information acquisition, diffusion, and interpretation have become critical in today's world for both human growth and nation-state sovereignty, scientific instruction and practice have taken on an important role in the educational process of youth (BERBEL, 2011). The goal of science is to generate and understand the information that humanity has accumulated over time (ARAÚJO, 2006). Despite this perennial character, the practice of science also reflects the intellectual, economic, and social interests of the time, as well as the tireless human curiosity to understand the nature (NUNES, 1993). The pursuit of scientific knowledge leads to a deeper understanding of society. In this approach, scientific education helps young people develop their citizenship by teaching them ethical, cultural, and playful values while engaging them in scientific work.

The pedagogical research proposal of the Science and Technology workshops integrates contents from different subjects, which get closer to the reality of the students' lives and encourages the creation of scientific initiatives that benefit culture and society, promoting a diverse view of reality and a greater knowledge of it. As a result, the students demonstrated improvements throughout the process, presenting their thoughts with increased clarity and reason, and becoming participants in the development of scientific knowledge.

Final remarks

The Science and Technology workshops provided students with the opportunity to learn science in a creative, investigative, contextual, problematizing manner, as well as to exercise creativity in data collection and interpretation while maintaining a critical attitude in participants toward their surroundings and existing scientific knowledge.

In addition to the intellectual competence and social cohesion required to create an inclusive and democratic society, education must give a comprehensive formation for citizenship. In order to give all students competent scientific teaching that enables them to exercise critique, ethical positioning, and democratic practice, public basic education schools must explain themselves when presented with complex and competing scientific issues.

The science workshops and the ensuing inquisitive pedagogy significantly helped students learn more. Student performance improved considerably between the first and last months of the workshop, indicating that the workshop technique was effective and fostered enhanced student learning. The scientific workshops create many pieces of information that are passed on to others in a spectral and capillary manner through the words of the institution's pupils. In this approach, new forms of scientific experience are created, and representations and misunderstandings – which become more and more common due to the rampant science denial in society – are deconstructed.

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