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Research article

The Impact of the Lack of Chemistry and Physics Laboratories in Schools

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Abstract

The deficiency of chemistry and physics laboratories in schools has profound implications for scientific education, as illuminated by a study conducted in Covasna County. Deprived of laboratory access, students lack the opportunity to experiment with chemical and physical phenomena, limiting the application of theoretical knowledge. This shortfall may foster a superficial understanding of the subjects and potentially dampen enthusiasm for science. Moreover, the absence of exposure to laboratory equipment and techniques stunts the cultivation of practical and critical skills crucial for scientific or technical careers, hindering students' preparation for future pursuits in these fields. Practical skills and a deep comprehension of scientific principles are indispensable for success in such careers. The absence of laboratory experience may place students at a disadvantage in university admissions or job competitions. It is imperative to implement viable solutions - investments in laboratory infrastructure, additional training for educators, and the development of interactive learning programs compensating for the dearth of practical experience. Integrating modern technology into the educational framework offers alternative avenues for experimentation and practical learning, mitigating the absence of physical laboratories. The study, conducted via an online questionnaire involving 61 school respondents, underscores the adverse impact of lacking chemistry and physics laboratories on students' learning and development. However, by implementing solutions, the situation can improve, ensuring students receive comprehensive and equitable science education. Addressing this deficit is pivotal in nurturing the next generation of scientists and innovators, equipping them with the skills needed to tackle real-world challenges and contribute to scientific progress.

Keywords:
scientific education, experiment, practical skills, laboratory

1. Introduction

In a world driven by science and technology, quality scientific education is essential for developing the necessary skills for the labour market. However, in many schools, the lack of chemistry and physics laboratories is a major barrier to achieving a comprehensive education in the sciences. This article aims to explore the causes and consequences of this issue, as well as potential solutions.

Chemistry laboratories have evolved from the workshops of alchemists to modern, high-tech research facilities. This evolution has been driven by scientific and technological revolutions, industrial needs, and ongoing investments in education and research. Chemistry and physics laboratories have been, and continue to be, bastions of scientific research with a spectacular evolution over the centuries (Principe, 2011). From the dark workshops of medieval alchemists to the ultra-modern laboratories of today, these spaces have witnessed numerous revolutionary discoveries. In the 17th century, Robert Boyle, considered the father of modern chemistry, made the first fundamental change described in his work "The Sceptical Chymist" (1661). Boyle promoted the scientific method and emphasized controlled and reproducible experiments. His laboratory was one of the first organized spaces for systematic scientific research, laying the groundwork for future chemistry and physics laboratories (Principe, 2011).

Another great scientist, Antoine Lavoisier, known as the father of modern chemistry, played a crucial role in the development of chemistry laboratories. In the 18th century, Lavoisier introduced the concept of mass conservation and defined chemical elements. His laboratory, equipped with precise balances and instruments for measuring gases, was an example of rigorous methodology. Lavoisier established standards for chemical research that are still respected today (Crosland, 2004).

The evolution of science laboratories is a fascinating story of scientific and technological progress. From medieval alchemists dreaming of turning lead into gold to modern scientists manipulating molecules at the atomic level, chemistry and physics laboratories have always been at the centre of great discoveries. Continuing this tradition of innovation and scientific rigor, chemistry and physics laboratories will remain essential for the future of science and technology. This historical trajectory demands continuity in the present, as, in addition to the great discoveries achieved through research, it is vital for students to experiment and personally reinvent fundamental chemical and physical phenomena. Experiments such as the decomposition of carbonic acid or the formation of oxides through burning not only illustrate theoretical concepts but also stimulate curiosity and passion for science. Thus, science laboratories become places where knowledge intertwines with direct experience, preparing students for the scientific challenges of the future and inspiring the next generation of researchers and innovators.

Chemistry and physics laboratories play a crucial role in the learning process. They offer students the opportunity to apply theory in practice, conduct experiments, and directly observe scientific phenomena. These practical activities not only reinforce theoretical knowledge but also stimulate critical thinking and problem-solving skills (Ardelean, 2010).

In many schools in Romania, chemistry and physics laboratories are either absent or insufficiently equipped. According to a report by the Ministry of Education, in 2020, almost 40% of rural schools did not have functional laboratories for scientific disciplines. In urban areas, although the situation is relatively better, many schools still face outdated equipment and insufficient materials or have given up laboratories to increase classroom capacity.

The lack of chemistry and physics laboratories has severe consequences for the quality of scientific education. Students who do not benefit from practical activities are less prepared for national exams and careers in the scientific field. Additionally, the lack of access to laboratories can diminish students' interest and motivation for science, leading to a decrease in the number of students in STEM fields (Science, Technology, Engineering, and Mathematics) (Cucoș, 2014). The absence of laboratories directly affects the quality of scientific education. Students who do not benefit from practical activities struggle to understand and apply theoretical concepts, reflected in poor results in national and international exams. According to the 2019 TIMSS (Trends in International Mathematics and Science Study), Romania ranked 36th out of 58 countries in science, well below the international average.

The increasing complexity of the educational act, interactivity, flexibility, and the open nature of education, research in educational sciences, globalization, and comparative pedagogy are elements that necessitate the introduction of an interdisciplinary character (Albulescu, 2016). Meeting children's needs and demands and achieving the harmonious and complex development of the educable, can be realized through the interaction of three forms of education: formal, non-formal provided by Children's Palaces and Clubs, and informal (Bocoș, 2017).

Research highlights the role of these forms of education in reducing school dropout rates and complementing quality education by developing personality and key competencies.

2. Statement of problem

In the modern educational system, chemistry and physics laboratories play a crucial role in developing students' scientific skills. These laboratories provide unique opportunities for practical learning, translating theoretical knowledge into practical applications, allowing students to apply theoretical knowledge in real experiments, and developing essential skills such as critical thinking, problem-solving, and teamwork. However, many schools in various regions face a severe lack of adequate or functional chemistry and physics laboratories. According to a report published by the Ministry of Education, approximately 40% of schools in Romania do not have properly equipped chemistry and physics laboratories. This issue is exacerbated by factors such as insufficient funding for the educational system, inadequate resource prioritization, and a lack of qualified personnel to supervise and maintain these laboratories. In larger schools, laboratories have often been dismantled in favour of classrooms (Bocoș & Ionescu, 2017).

Without access to chemistry and physics laboratories, students are deprived of vital educational experiences, which can lead to a superficial understanding of scientific concepts and decreased motivation to study science. The impact of this situation is significant not only on students' academic performance but also on their preparation for careers in scientific and technical fields (Bocoș & Ionescu, 2017). In a world where technological and scientific advances are essential for societal progress, the lack of a solid scientific education can have long-term consequences on national and global competitiveness and innovation. A study by the OECD has shown that students who benefit from well-equipped laboratories perform better in science exams and are more inclined to pursue careers in STEM fields.

In an educational system where school chemistry and physics laboratories are insufficiently equipped, children's palaces and clubs offer valuable alternatives for developing science skills. These extracurricular institutions provide programs and activities designed to complement formal education, emphasizing practical learning and experimentation (Kerekes, 2022). The interactive and experimental activities offered by Children's Palaces and Clubs are more engaging than theoretical lessons, thus stimulating students' interest and motivation for studying science. This is essential for attracting more students to STEM careers. Non-formal education must complement formal education because, in such situations and beyond, it can be an alternative for education in science and technology (Kerekes, 2018).

In the short term, students without access to chemistry and physics laboratories tend to struggle with understanding theoretical concepts, leading to lower grades and overall reduced academic performance. The lack of practical experiences can diminish students' interest and enthusiasm for chemistry and other scientific disciplines. Students in schools without adequate laboratories are disadvantaged compared to those in better-equipped institutions, thus contributing to increasing educational disparities. In the long term, students without a solid practical background in chemistry and physics may be poorly prepared for higher education and careers in scientific and technical fields, thus affecting the future workforce. A weak educational foundation in science can limit a nation's capacity to innovate and remain competitive on the global stage. The lack of laboratories can lead to decreased interest in STEM careers, which can negatively impact long-term technological and scientific development (Bocoș & Ionescu, 2017).

Another aspect to consider is the methodology of teaching chemistry and physics. The experimental method is fundamental for understanding and applying theoretical concepts. It involves placing students in situations where they conceive and conduct different types of experiments to observe, study, verify, and measure results. These experiments are conducted under controlled conditions, intended to provoke specific phenomena and allow for their observation. Through this, students can investigate causal relationships, discover the laws governing phenomena, and verify various scientific hypotheses. In the laboratory setting, the experiment serves as a heuristic method for organizing and conducting practical activities (Cucoș, 2014). This facilitates the deduction of theoretical information, concretizes and verifies knowledge, and deepens and consolidates students' psycho-motor skills. At the same time, it prepares students for socio-professional integration, stimulating their interest in chemistry and physics. As experimental sciences, chemistry and physics rely on experiments both as a method of scientific investigation and as a learning method. In the process of learning through experimentation, students are actively involved in provoking phenomena, observing effects, and verifying hypotheses (Cerghit, 1980).

Experiments can be used to stimulate interest in new information, for learning and consolidating concepts, or for applying them in homework assignments. It remains a form of independent student activity and an effective way to develop interest in chemistry and physics as sciences. Laboratory experimentation not only stimulates students' interest in new information but also facilitates the learning and application of new concepts, thus consolidating their theoretical and practical knowledge (Cerghit, 2006). In chemistry and physics, as experimental sciences, this method is crucial for scientific investigation and learning, provoking phenomena, observing their effects, and verifying hypotheses (Cerghit, 2006). The laboratory experiment is an essential heuristic method for organizing and conducting practical activities, helping students deduce theoretical information, verify hypotheses, and consolidate their knowledge and psycho-motor skills (Cerghit, 2001).

3. Research methodology

An online questionnaire study was conducted from September 2023 to April 2024 in Covasna County, Romania, encompassing a sample of 61 financial centres. Statistical analyses were performed using the SPSS24 program. The online questionnaires were structured around ten questions, focusing, among other things, on the role of experiential learning in teaching methods and the use of investigative methods as a component of teaching chemistry and physics.

An evaluation was conducted between an experimental group that frequently used experimental methods in their activities and a control group that had minimal experimental activities. Measurement was based on an online test with ten questions.

The questions aimed to assess:

How does access to chemistry and physics laboratories influence the development of scientific, technological, and analytical competencies in middle school students compared to theoretical teaching methods without practical components?

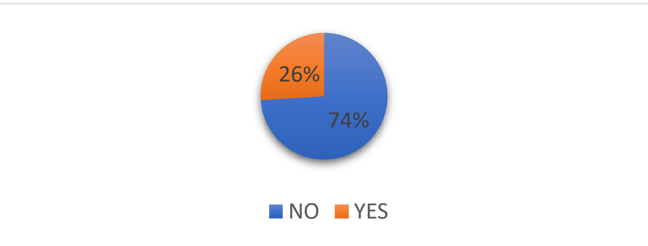
4. Results

Laboratories provide students with essential tools to understand the reality around them. Students primarily learn through investigation, tackling problems, analysing data, and understanding chemical and physical relationships to find optimal solutions. By alternating teaching, learning, and evaluation methods and emphasizing experiential learning, students become aware of their intellectual capabilities. The investigative method helps students formulate questions about various chemical phenomena, seek explanations, identify cause-effect relationships, and develop critical thinking skills (Bocoș, 2017).

Activating students enhances the efficiency of educational activities, stimulates intellectual activity, and encourages initiative and independent research (Albulescu, 2008). Student engagement in science can be achieved through attractive experiments that bring the real world into laboratories, allowing students to reinvent and investigate natural phenomena.

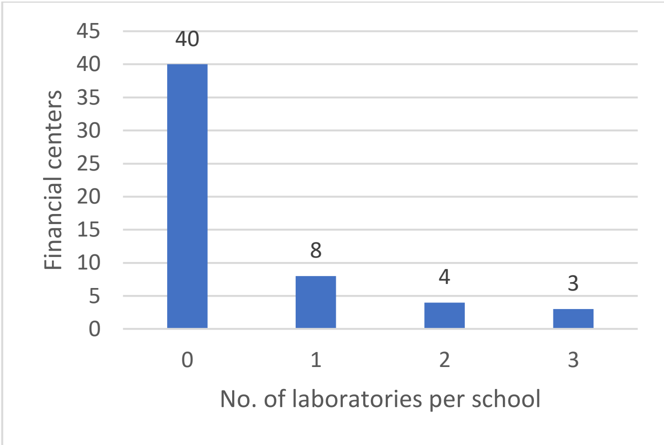
Covasna County is one of the regions where 74% of financial centres lack chemistry and physics laboratories.

Figure 1.
The situation of the chemistry, physics laboratories-county Covana



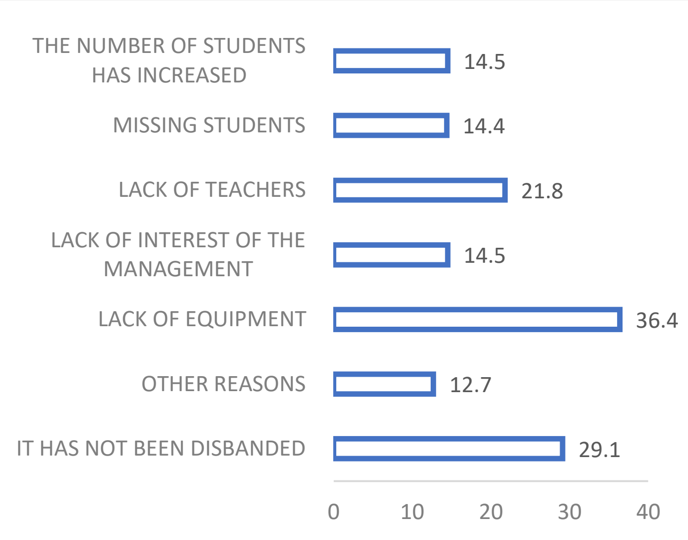
Covasna County has 78 financial centres that serve local community schools and kindergartens. The survey results (Figure 1) indicated that 74% of these financial centres do not have chemistry and physics laboratories or do not use them due to inadequate equipment and a lack of qualified personnel. The absence of chemistry and physics laboratories in 74% of schools has a significant negative impact on the development of students' scientific, technological, and analytical competencies. Without access to laboratories, students cannot directly experience theoretical concepts, which limits practical learning and the development of critical skills such as analytical thinking and problem-solving. This situation diminishes motivation and interest in the sciences and inadequately prepares students for advanced studies and careers in scientific fields (Bocoș, 2017). This creates a disparity between schools with laboratories, where students benefit from a more comprehensive education and increased opportunities for academic and professional success. Another consequence of the lack of laboratories is increased school dropout rates, especially for students from peripheral areas who are "transferred" to better-equipped schools. This can lead to the closing of some schools due to a lack of students.

Figure 2.
Number of laboratories by financial centers



According to the survey conducted (Figure 2), 40 of these financial centres lack any laboratories, and only 8 schools are equipped with a single laboratory. Urban schools show a slightly better situation: 4 schools each have two laboratories, while another 3 schools benefit from three laboratories each. This variation highlights significant discrepancies in students' access to essential educational resources, such as direct experimentation and the practical application of theoretical concepts in a laboratory setting. The repercussions of such distribution are considerable. Schools that lack laboratories or have limited access to them face major challenges in providing students with authentic and interactive learning experiences in scientific fields. This can lead to an incomplete preparation of students in critical competencies, such as analytical thinking and problem-solving, placing them at a disadvantage compared to students who have access to well-equipped laboratories. The discrepancy creates educational inequities, affecting student motivation and influencing decisions regarding continuing education or school dropout (Bocoș & Ionescu, 2017). To counter these issues, it is crucial to implement educational policies and allocate adequate resources to ensure that all schools have appropriate infrastructure for scientific education.

Figure 3.
The science laboratories/laboratory in your school have/have been disbanded from (%)



Chemistry and physics laboratories in Covasna County have been dismantled for various reasons (Figure 3), each reflecting the unique challenges faced by educational institutions in the region. According to the survey, the following reasons were identified:

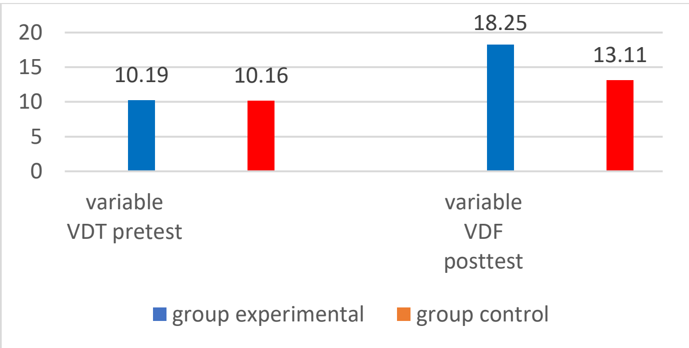
- lack of students (14.4%): some schools were forced to dismantle laboratories due to the low number of enrolled students, making it difficult to justify maintaining and funding these facilities,
- increase in student numbers (14.5%): this led to the conversion of laboratories into additional classrooms to accommodate the overcrowding in urban schools,
- lack of specialized teaching staff (21.8%): a major issue was the shortage of qualified teachers in chemistry and physics, making it impossible to use existing laboratories effectively, which ultimately led to the closing of these modern education segments.
- lack of interest from school management (14.5%): in some institutions, school management did not prioritize the maintenance and use of chemistry and physics laboratories, leading to their neglect and eventual closure.
- other reasons (12.7%): this includes various other factors such as inadequate funding for equipment and materials, logistical and administrative issues, or unfavourable educational policies.

These reasons illustrate the complexity of the problems schools face in maintaining laboratories. The absence of these facilities has significant repercussions on the quality of education provided. Students are deprived of essential opportunities for experiential learning, limiting the development of scientific, technological, and analytical skills.

Without laboratories, students cannot directly experiment with theoretical concepts, which limits practical learning and the development of critical skills such as analytical thinking and problem-solving (Cucoș, 2014). The lack of laboratories contributes to significant educational inequities and creates a risk of school dropout. Schools with well-equipped laboratories provide their students with a more comprehensive education and increased opportunities for academic and professional success. In contrast, schools without laboratories cannot offer the same level of preparation, which can negatively impact students' motivation and interest in science, leading to school dropout, especially in areas on the outskirts of cities. This phenomenon can ultimately lead to the closure of some schools due to declining student numbers, exacerbating educational problems in the county.

Research, testing, and data processing after seven months of activities demonstrate the effectiveness of experiments in developing competencies and highlight the importance of laboratories and experimental methods in education. This was conducted in multiple schools, with pre-test and post-test questionnaires focusing on measuring competency development, primarily through structured scientific investigation and experimental methods. Experimentation remains an action of exploration, a provoked observation, a trial, a search for evidence, and discovery of laws through conducting experiments (Albulescu & Catalano, 2019).

Figure 4.
Comparison of results for the dependent variable V.D between the experimental and control groups



According to Figure 4, both the experimental and control groups start from similar levels of development for the competency V.D., namely 10.19

and 10.16, respectively. After conducting activities over seven months, it is observed that the experimental group shows a significant variation between pre-test and post-test results, with a change of 8.06, compared to the control group with a change of 2.95. It can be concluded that the differences in results are significant in the experimental group and are attributed to the independent variable (the use of experiments in each activity).

To measure the relationship between the mentioned variables, two hypotheses were formulated:

H_0-null hypothesis: following the completion of the school programs (both the control group and the experimental group) and the implementation of the intervention program (experimentation) — which in this case involves the experimental method applied to the experimental group — there is no significant difference between the results obtained regarding the dependent variable V.D. ($VD_{EF}=VD_{CF}$) between the experimental and control groups.

H1-research hypothesis: following the completion of the school programs (both the control group and the experimental group) and the application of the experimental method to the experimental group, there will be a significant difference in the results regarding the dependent variable V.D. ($VD_{EF}\neq VD_{CF}$) between the experimental and control groups.

Table 1.

Data, including the average results obtained from conducting a t-test to compare the dependent variable V.D. between the experimental group and the control group

	Lot groupe	**N**	**Average**	**Average difference**	**Standard error difference**
VD_{CT}	Group experimental	57	10,199	4,53291	,57110
	Group control	58	10,166	5,12293	,61695
VD_{CF}	Group experimental	57	18,256	4,16410	,53124
	Group control	58	13,111	5,1234	,61117

According to the analysis of data presented in Table 1, students in the experimental group exhibited an increase in the mean results for the dependent variable V.D. by 5.112, compared to students in the control group, who only followed the school curriculum using traditional methods without the experimental approach.

Table 2.

Data collected from applying the t-test, comparing the dependent variable V.D., experimental group and control group

VD_{CT}	testul Levene -pentru egalitatea varianțelor		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Differ-Ence: Average	Standard error difference	95% I Confidence Interval for Differences Reduced	Grown
Equal variances assumed	,005	,924	,029	127	,952	,02564	,81171	-1,514	1,7770
Equal variances not assumed			,032	126,626	,952	,02667	,81171	-1,514	1,7770
Equal variances assumed	,279	,513	7,49	127	,000	6,1323	,79032	4,6283	7,0840
Equal variances not assumed			7,773	126,375	,000	6,453331323	,79032	4,6273	8,08414

$F=0.279$, $p_F=0.513$, $t(127)=7.773$, $p=0.000$

The Levene's Test (Table 2) shows a non-significant result (F=0.279, p=0.513), indicating that there is a 51.3% chance of incorrectly rejecting the null hypothesis that assumes equal variances. Therefore, the variances between the two groups are equal, and results are extracted from the row assuming equal variances. The results obtained are t(127) = 7.773, p=0.000. The p-value is below the theoretical significance threshold, indicating that the results are significant. Based on this statistical comparison, it can be asserted that students who predominantly used the experimental method achieved significantly better results regarding scientific investigation competencies. Hence, the research hypothesis is supported.

The analysis of the differences in the post-test and pre-test results, presented in Figure No. 1 and Table No. 2, shows that the dependent variables: the ability to conduct structured scientific investigations, primarily experimental, of simple chemical and physical phenomena, which means: exploring the properties and physical and chemical phenomena within simple investigations; the ability to use methods for recording and representing experimental data; the ability to formulate simple conclusions based on the experimental data obtained during technical-scientific investigations; the ability to interpret the effects of technological development and awareness of the consequences that improper exploitation can have on environmental protection, form the development of competence in science and technology, are more significantly formed in students who use the experimental method compared to students who only follow school programs without experimenting (Stan, 2001).

The results are as realistic as possible, since the school programs for the subjects Physics and Chemistry were introduced in the 2017-2018 school year, programs that aimed at scientific investigation skills, which play a determining role in the technological education of students. The experiments used in almost every class/activity complement this, helping to develop the skills for investigating phenomena, interpreting data, solving problems and problem situations, i.e., those skills that will be necessary for the socio-professional integration of the student in everyday life.

Empirical evidence supports the efficacy of experiments and confirms the research hypothesis. The research, consistent with specialized studies, supports that experiments help students develop competencies in science and technology (resulting in higher academic performance), diverse practical skills, and appropriate problem-solving strategies.

5. Conclusion

To address these issues, it is crucial to implement measures that support the maintenance and development of laboratories. This includes investing in infrastructure, attracting and retaining specialized teaching staff, and implementing educational policies that prioritize scientific education. These actions will contribute to improving the quality of education in Covasna County and reducing school dropout rates.

This article explores the implications of the lack of chemistry and physics laboratories in schools and seeks to identify solutions to overcome these challenges. It emphasizes the need for investment in educational infrastructure and the importance of supporting scientific education.

By addressing these issues, we can hope to provide students with access to the resources necessary to reach their full potential and become future leaders in science and technology. The lack of chemistry and physics laboratories in Romanian schools is a complex problem that contributes to the high dropout rate and requires concerted and sustained actions from authorities, the educational community, and society as a whole.

Investments in scientific education are essential for preparing students for the future and developing a knowledge-based and innovative society. It is our collective responsibility to ensure access to quality scientific education for all students so that they can actively contribute to the progress and well-being of society and reduce school dropout rates.

Authors note:

Jenő Kerekes, is a chemistry and physics teacher at "Váradi József" Secondary School in St. George, a school that places great emphasis on quality and well-being of students. He taught applied electronics and experimental chemistry at the Children's Palace in Sf. Gheorghe where he is still the director. The research for the PhD was conducted in the field of curricular area mathematics and natural sciences, combining the two activities, formal education and extracurricular education, aiming at the complementarity of creative but at the same time educational technical, scientific activities at the Children's Palace with formal technical-scientific activities. All research was guided by prof. univ. dr. habil. Ion Albulescu.

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