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Fairy Tale as a Tool of (Scientific and Technical Education) STEM Education for Children

Abstract

The article *aims* to provide scientific evidence and empirical confirmation of the effectiveness of using fairy tales as a teaching tool to develop STEM competencies in children. The article reveals the potential of fairy tales as a pedagogical tool for integrating humanities, natural sciences, and technology in a single educational environment. *Methodology.* The study is based on a combination of theoretical modelling and empirical verification, in the form of a questionnaire survey of 235 teachers. The survey is structured into three analytical categories: productive indicators (level of understanding of cause-and-effect relationships, validity of explanatory models, quality of engineering solutions, and ability to transfer knowledge to new contexts); procedural indicators (development of critical thinking, logical sequence of reasoning, and collaborative interaction in educational activities); methodological indicators (effectiveness of epistemic framing, use of modelling as a tool for testing hypotheses, and formation of reflection on the boundaries of knowledge). *Results.* Generalisation of the empirical data revealed a high level of pedagogical recognition of the effectiveness of fairy tales in STEM education. The majority of respondents (63.0%) consider fairy tales to be an effective means of forming an understanding of cause-and-effect relationships in natural and technical phenomena, while 51.5% consider them to be an effective tool for developing design and modelling skills. Over two-thirds of respondents (69.8%) noted the positive impact of the fairy-tale context on critical thinking development, and 60.0% emphasised its role in fostering co-operation skills. At the same time, indicators of the reflective component remain low (37.5%), suggesting a need to enhance metacognitive skill development and scientific knowledge boundaries awareness. *Practical significance.* The results obtained confirm the effectiveness of fairy tales as an integrative didactic tool in STEM education, capable of ensuring the cognitive, emotional and social integrity of the educational process. The proposed approach can form the basis of educational modules aimed at developing critical, engineering and reflective thinking skills in schoolchildren. The *scientific novelty* lies in the development and empirical confirmation of a model for assessing the effectiveness of fairy tales in STEM education. This model combines productive, procedural and methodological indicators to form a new approach to the study of narrative technologies in scientific and technical education.

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1 Introduction

In the context of the modern transformation of the educational system, there is an increasing demand for innovative pedagogical tools that can integrate humanitarian, natural and technical knowledge within a single educational environment. One such universal tool is the fairy tale, which, transcending its traditional literary genre, becomes a didactic tool for developing STEM competencies in children. Modern pedagogical science considers fairy tales to be cognitive-emotional learning mechanisms that combine the intellectual, value-motivational and creative aspects of a child's development, thereby contributing to

the development of critical, logical and research thinking skills.

The peculiarity of using a fairy tale as a didactic tool lies in its combination of aesthetic and scientific-cognitive elements. Its plot, filled with fantastical elements, creates an epistemic situation – a comparison of the imaginary and the real – which encourages students to question their assumptions, develop explanatory models, and identify the limits of scientific plausibility. Therefore, the fairy tale acts as a cognitive interface between artistic narratives and scientific and technical thinking. This ensures a harmonious combination of emotional involvement and rational analytical activity. For this reason, it is

Keywords

STEM education, fairy tale, critical thinking, engineering modeling, epistemic framing

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considered a promising tool in the context of STEM education, which focuses on developing a systematic, creative and research-based approach to learning.

Despite growing scientific interest in fairy tales, most studies focus on their role in children's speech, moral or social development, ignoring their potential as an integrated teaching tool for natural science and technical disciplines. Consequently, it is becoming increasingly important to determine the pedagogical effectiveness of using fairy tales to develop STEM competencies and research thinking skills in primary school students.

The study aims to scientifically substantiate and empirically confirm the effectiveness of using fairy tales as a didactic tool for developing STEM competencies in children. To this end, the following tasks have been defined: determining the level of pedagogical recognition of fairy tales as a means of integrating humanities and science knowledge; assessing the procedural and methodological conditions for their effective use in STEM education; and outlining the prospects for improving pedagogical technologies that combine narrative and research-based learning.

The study is based on an empirical survey of 235 teachers. The results enabled leading trends to be identified, the pedagogical feasibility of using fairy tales in a STEM context to be assessed, and recommendations to be formulated for the further development of integrative educational practices.

2 Fairy Tale in the Educational Process

In modern pedagogical theory and practice, fairy tales are considered universal cognitive and emotional tools for developing a child's personality. They combine elements of aesthetic perception, moral education and cognitive activity (Danyliuk & Zolnikova, 2019). Traditionally, fairy tales have been used in education to develop speech skills and vocabulary, as well as to foster communication skills, critical thinking, and the ability to recognise cause-and-effect relationships. By interpreting the text of a fairy tale, a child can learn the structure of language, understand the semantic ambiguity of words, and transform figurative and associative elements into logical constructions (Hammel, 2018).

Fairy tales contribute to a child's socio-psychological development by acting as a mediator between their internal emotional experience and the external social context. Through the plot's dynamics, children learn to differentiate between basic ethical categories such as good and evil, courage and cowardice, and truth and lies. This creates the prerequisites for the development of moral reflection and ethical responsibility (Jorgensen, 2021). In this respect, fairy tales are a form of cultural code that helps children integrate into systems of social norms and shared values,

forming positive identities and attitudes towards collaboration (Kazachiner, Boychuk & Halii, 2022).

Fairy tales have a special significance as psychotherapeutic and art-therapeutic tools for correcting emotional and behavioural disorders in children. Its therapeutic potential is based on the ability to experience and transform internal fears, anxieties and conflicts symbolically through narrative and creative activity (Kole, 2018). Depending on the child's psycho-emotional state, therapeutic fairy tales can be categorised by their intended function, such as reducing anxiety, overcoming aggressiveness and hyperactivity, and supporting children through loss, family conflicts, and crisis situations (Kuciapiński, 2014).

It's worth pointing out that working with a fairy tale can mean doing all sorts of things, from the more traditional like reading and text analysis, to some really creative activities like creating one's own fairy tales, playing role-playing games, modelling characters or visualising plots through drawing. These methods integrate cognitive and emotional experiences, fostering creative thinking, empathy, and reflexivity (Ruban et al., 2024).

From the perspective of modern STEM pedagogy, the fairy tale is considered not only a form of cultural reflection, but also an effective tool for modelling interdisciplinary thinking. Its plot structure can be reinterpreted in the context of problem-based learning, where it becomes the basis for forming research questions, hypotheses, and project solutions in science, technology, engineering, and mathematics (Schubert, 2020). Consequently, integrating fairy tale narratives into STEM education fosters cognitive flexibility, systems thinking, and creative problem-solving – all of which are essential 21st-century competencies.

Thus, a fairy tale is not only a cultural and aesthetic phenomenon, but also a complex psychological and pedagogical tool that can transform the educational environment into a dynamic space for research, experimentation, and creativity. In STEM education, its potential lies in its ability to strike a harmonious balance between a child's emotional and cognitive development, forming the foundations of holistic thinking that combines humanitarian and technical knowledge.

3 Fairy Tales as a Tool for STEM Education

The use of fairy tales as a didactic tool in STEM education is considered a controlled "epistemic situation", deliberately colliding the imaginary with the real to initiate cognitive conflict, directing students to test assumptions and build explanatory models, as well as explore the limits of knowledge applicability. The theoretical basis of the study is the constructivist paradigm, which assumes the active construction of knowledge by the student; the

socio-cultural approach, which considers learning as a process of interaction in a cultural context; research learning, focused on the independent discovery of patterns; the model of conceptual change, aimed at overcoming everyday ideas about phenomena; and the model of metacognitive regulation, which provides awareness and control of one's own cognitive activity. When the aforementioned theoretical guidelines are taken into consideration, the logic of implementing the method is revealed through six interconnected phases of the educational process.

The didactic mechanism of the method is implemented as a sequence of six interconnected phases. First, narrative exposition creates a motivational background and a shared context through brief immersion in the plot. This is followed by epistemic framing, which involves explicitly outlining the rules of interpretation, emphasising that a fairy tale is a literary text and that scientific conclusions require verification. The next phase focuses on the identification of statements, where the fact-fiction procedure is operationalised as students distinguish between events and attributes that align with empirical patterns and those that contradict them. After this, counterfactual modelling is introduced through "what if?" questions that vary system parameters and encourage comparison between expected outcomes and established laws. This leads into modelling and verification, where students construct simple physical, graphical or computational models to explain phenomena without resorting to supernatural causes, and then verify these models for consistency with data or theory. Finally, reflective consolidation reinforces the concepts learned, clarifies the limits of their applicability, and demonstrates how they can be transferred to new situations.

The proposed approach to using fairy tales in STEM education demonstrates a high level of interdisciplinary integration by combining artistic narrative with natural scientific thinking, engineering logic, and elements of scientific modelling. Due to its metaphorical structure, the fairy tale becomes a heuristic field in which children can immerse themselves in a creative plot while carrying out analytical activities based on scientific principles. This learning format provides cognitive flexibility, critical analysis and the creative application of knowledge—the essence of the modern STEM paradigm.

For example, the analysis of the fairy tale "Cinderella" is carried out according to the principles of realism and scientific plausibility. In particular, scenes depicting clothing production facilitate the consideration of the properties of materials, texture, and the technological processes involved in fabric production. These elements correlate with those of applied physics and materials science technology. Conversely, scenes depicting Cinderella interacting with animals, such as birds or mice, necessitate a

reinterpretation through the lens of biological optics, shifting the focus from fantastical 'communication' to the actual mechanisms of animal communication, including visual signals, chemical stimuli, and acoustic waves. Thus, the artistic motif provides a foundation for establishing logical connections between the plot of the fairy tale and natural scientific laws, thereby developing observation, analytical and generalisation skills.

The fairy tale "Jack and the Beanstalk" represents another type of STEM integration, focusing on engineering and design. The motif of the beanstalk's vertical growth, which is described as magical in the text, is translated into a realistic context through an analysis of the principles of mechanics and civil engineering. Factors such as structural integrity, load, gravity, self-weight and the resistance of materials are considered to determine the feasibility and limitations of such a phenomenon. During the learning process, students can design and create models of lifting structures, ranging from simple block systems to screw or rack-and-pinion mechanisms. This helps them to understand the principles of statics, kinematics and energy costs. In turn, this ensures the development of systems thinking, the ability to perform technical analysis, and the ability to transfer knowledge from scientific theory to practical engineering activities.

The analysis of the episode involving a change in body size in the fairy tale "Alice in Wonderland" is equally revealing, as it opens up the possibility of studying the principles of scaling in biology and physics. It is evident that the aforementioned plot facilitates the elucidation of the ratio of surface area to body volume, the physiological limits of metabolism and diffusion, and the mechanical limitations that affect the vital activity of organisms of varying sizes. The analysis of a fantastical motif from a scientific perspective has been demonstrated to engender an understanding of the laws of the natural world and to enable the identification of the boundaries of what is feasible in real science. This is a crucial component in the development of critical thinking (Kotsis, 2024).

Analysing the fairy tale "The Turnip", one can discover its rich educational potential in developing STEM competencies. Most importantly, the plot reflects cause-and-effect relationships (planting – growth – harvest), enabling children to develop an understanding of natural processes, sequences of actions, and the laws of nature. The transformation of potential into reality (seed → fruit) introduces children to the fundamentals of the biological cycle and the concept of growth energy. The gradual addition of new participants embodies the law of the transition of quantity into quality, showing children that only collective interaction leads to a result. This moment opens up the possibility of STEM tasks related to the study of force, leverage,

the proportional distribution of effort, and the balance of the system. Even the mouse paradox, the final element ensuring success, demonstrates the system's sensitivity to small influences, a principle that can be explained through catastrophe theory or the model of unstable equilibrium. Therefore, the fairy tale plot provides material for scientific modelling and simple experimentation within the capabilities of children of this age.

In addition to its cognitive dimension, the fairy tale "The Turnip" encourages the development of figurative thinking in the right hemisphere of the brain, which is a prerequisite for creativity and innovation in STEM subjects. The process of hidden grain growth fosters an understanding of natural cycles, invisible processes and patterns that necessitate observation and explanation. The metaphorical image of a turnip as a "result of life" enables children to understand the relationship between action and consequence, and between effort and outcome, which has philosophical and pedagogical significance.

The speech and socio-moral aspects of this tale are important, too. Its brevity and rhythm help to develop phonemic awareness and clear articulation. Through observing the characters' collective interactions, children learn the concepts of teamwork, mutual assistance, solidarity, and social responsibility. This aligns with modern education's competency-based approach, which incorporates the development of communication and social skills as part of STEM literacy.

Parallels can be drawn between V. Sukhomlynsky's story "The Feat of a Mosquito" and the fairy tale "The Turnip", in which the principle of a small factor having a paradoxical influence on a stable system is also implemented (Voznyuk, 2021; Voznyuk, 2025). This plot provides a pedagogical explanation of cause-and-effect changes, unstable equilibria and critical points in natural and social processes, forming the basis of a scientific worldview in children.

The practical implementation of the method involves using story-based role-playing games, interactive models and artistic and technical modelling activities, such as drawing, sculpting and construction, as well as scientific demonstrations. In these activities, children recreate physical, mathematical or biological phenomena presented in a fairy tale. These activities encourage children to develop the initial skills of research, analytical comparison, observation, generalisation and formulation of conclusions.

In the context of STEM education, the fairy tale "The Turnip" appears as a universal model of integrated learning, combining elements of the natural sciences, technical thinking, humanities and social interaction. Its pedagogical value lies in facilitating the cognitive development of children, encouraging research activities and fostering a holistic worldview. This approach ensures a harmonious combination of the scientific, technical and humanitarian aspects of

education, making the fairy tale an effective tool for nurturing future thinkers, researchers and creators (Sukhomlynsky, 2016).

Therefore, incorporating fairy tales into STEM education increases motivation to learn and ensures a comprehensive understanding of knowledge by integrating artistic and scientific thinking. As a cultural text, a fairy tale can be transformed into a pedagogical model of research activity, with each plot element providing an entry point to scientific analysis, experimentation, and modelling. Such an approach not only helps children to understand scientific laws, but also develops their ability to think systematically, prove things, verify them and apply knowledge in different contexts. This is the foundation of modern scientific and technical education (Kotsis, 2024).

4 Methodological Foundations for Evaluating the Effectiveness of Fairy Tales in STEM Education

The effectiveness of using fairy tales in the STEM education of children is assessed using a combination of productive and procedural indicators, which reflect the outcomes of learning and the quality of the learning process. Productive indicators include the validity of explanatory models, i.e., their logical consistency and correspondence to observed facts; the quality of engineering solutions is determined by how well the solution created by students corresponds to the task, whether they use materials appropriately and how logically they explain the choice of methods or mechanisms for its implementation; and the ability to transfer knowledge means the ability of students to use scientific ideas and principles learned during the analysis of the fairy tale in new educational tasks or real-life situations.

In turn, procedural indicators reflect metacognitive transparency (the ability to formulate criteria for distinguishing "fact" from "fiction"), epistemic discipline (the ability to distinguish an artistic metaphor from a scientific statement) and collaboration skills (the ability to coordinate positions rationally in collective activities). To ensure the objectivity of the assessment, it is advisable to use analytical rubrics with descriptive levels of achievement, as well as inter-expert verification procedures to guarantee consistent results and increase the reliability of interpretations.

The validity and scientific reliability of the approach are ensured by three interrelated conditions. First, epistemic framing is maintained both at the outset and throughout the process, clearly defining the narrative as artistic in nature and emphasising that any conclusions must be grounded in empirical evidence and aligned with theoretical models. This reduces the risk of forming pseudo-concepts and

preserves the scientific integrity of interpretations. Second, mandatory modelling ensures that students' verbal representations are systematically translated into external forms, such as diagrams, models, experiments or algorithmic descriptions, making their reasoning observable, structured and testable. Third, reflection on the boundaries of knowledge requires that each assumption is accompanied by an explicit consideration of the conditions of its validity, as well as its underlying assumptions and limitations. This prevents the substitution of fiction for science and fosters a rigorous scientific culture of thinking. Within the framework of the third condition, it is advisable to use modern technological narratives, particularly stories about artificial intelligence and robotics, to make an accurate comparison. Behavioural complexity and autonomy in machines are considered to be the result of algorithmic processes rather than a manifestation of "consciousness". This approach also supports the ethical principles of technological literacy (Kotsis, 2024).

5 Results of the Empirical Study

A survey of 235 teachers revealed a high level of recognition of the pedagogical effectiveness of integrating fairy tales as a means of incorporating the humanitarian and natural science components of STEM education. The majority of respondents

(63.0%) assessed the fairy tale as a "very effective" tool for forming an understanding of cause-and-effect relationships in natural and technical phenomena. Furthermore, 28.9% of respondents noted its partial effectiveness, thereby confirming the cognitive and developmental potential of the narrative form in the context of explaining complex patterns of the surrounding world.

The development of constructive and technical thinking has also been demonstrated to be a positive dynamic. 51.5% of teachers have observed that students often demonstrate design and modelling skills when working with fairy-tale plots, and a further 37.9% sometimes do so. This indicates the high adaptability of the fairy-tale format for implementing a practice-oriented approach and forming an engineering type of thinking in primary school children. The integration of the humanitarian narrative with technical creativity has been demonstrated to engender conditions conducive to the development of cognitive flexibility and the ability to apply knowledge in new contexts. This corresponds to modern principles of competency-based learning in STEM education (see Fig. 1).

In terms of procedural aspects, 56.2% of teachers confirmed that students can distinguish between fictional elements and real scientific phenomena in fairy tales. Another 37.0% demonstrated this ability to some extent. Thus, most children develop critical thinking at an early stage, which is necessary for

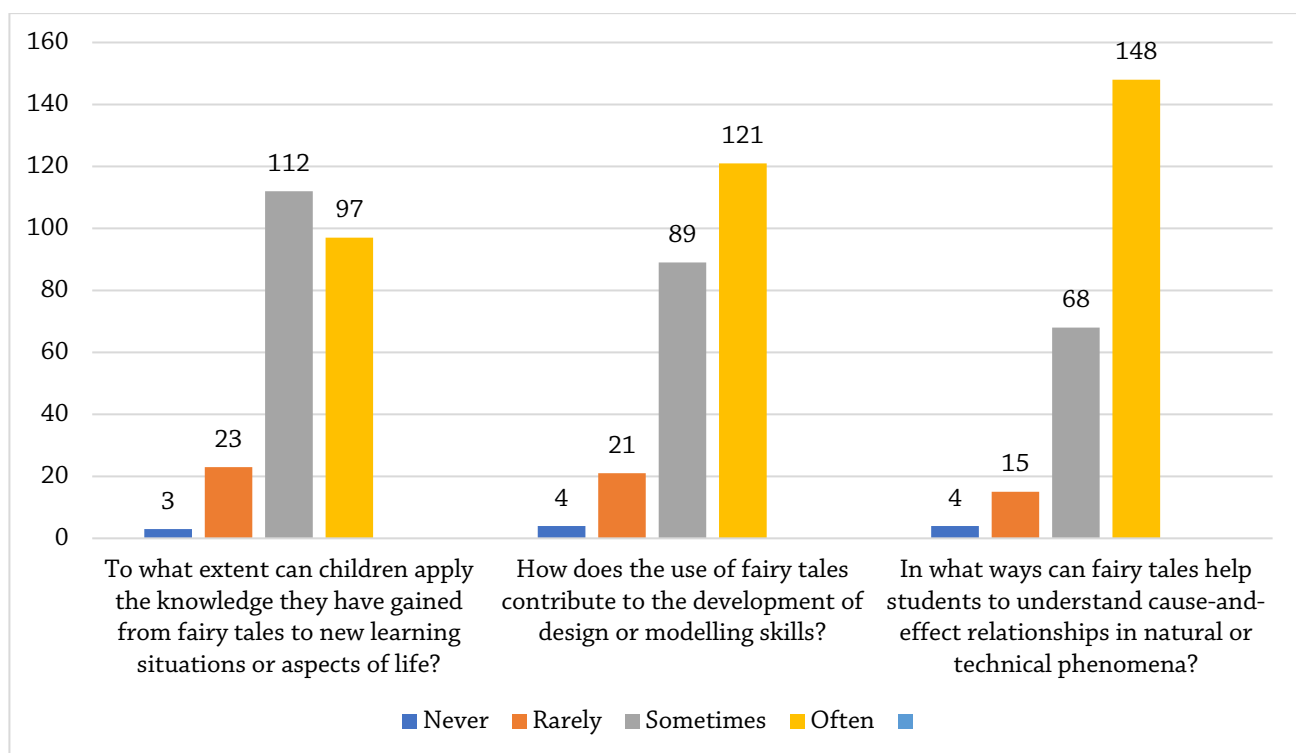


FIGURE 1 Distribution of teachers' responses by block "Evaluating the productive results of using fairy tales in STEM education"

Notes: author's own calculations

epistemic literacy. Additionally, 69.8% of respondents stated that working with fairy-tale plots significantly contributes to the development of logical thinking, while 60.0% noted an increase in co-operation among students, indicating the socio-communicative potential of the method (see Fig. 2).

Teachers also expressed high levels of support for the methodological aspects of the implementation. The vast majority (83.8%) of respondents considered it necessary to explain the difference between artistic and scientific content to students, which corresponds to the principle of epistemic framing of the educational process. At the same time, 44.3% of teachers regularly use modelling elements (such as schemes, models and experiments) when working with fairy tales, while 43.4% use them sporadically. These figures suggest the gradual integration of STEM methods into the humanities education context.

The reflective component of learning, whereby students become aware of the limits of their own knowledge and assumptions, was found to be the least developed. Only 37.5% of teachers noted that children had a good understanding of the limitations of their hypotheses, while 46.4% observed only partial awareness. This indicates a need to improve methods that develop metacognitive skills through analysing and discussing where fantasy ends and scientific explanation begins.

In summary, the majority of surveyed teachers positively assessed the use of fairy tales as an effective didactic tool in STEM education. High scores on

productive and procedural indicators suggest its potential for developing critical, logical and engineering thinking, as well as for fostering an emotionally safe learning environment. The data obtained confirm that integrating fairy tale narratives into the STEM curriculum contributes to the cognitive and socio-communicative development of children, ensuring a balance between the humanities and technology in modern education.

6 Conclusions

The results of the study confirm the high pedagogical effectiveness of using fairy tales to develop STEM competencies in children. Empirical data showed that most teachers recognise fairy tales as an effective means of integrating knowledge of the humanities and natural sciences, which contributes to the development of critical thinking, engineering and research skills. Fairy tale narratives have been shown to provide a deeper understanding of cause-and-effect relationships in natural and technical phenomena, while also creating a motivational safe space for grasping complex scientific concepts. Over half of the surveyed teachers (51.5%) confirmed that working with fairy tale plots stimulates students' activity in modelling and design, thereby developing their ability to apply knowledge to new educational and life situations. The study's process indicators demonstrate that integrating fairy-tale elements into STEM

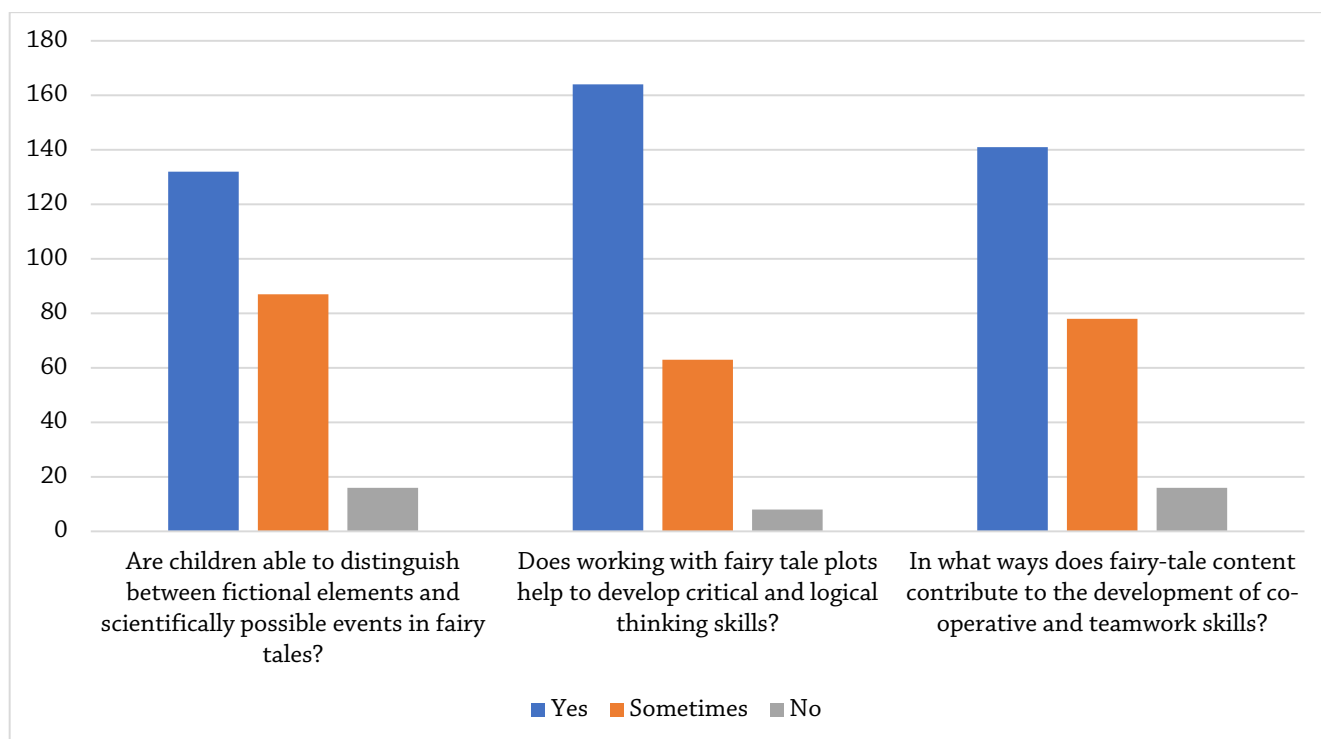


FIGURE 2 Distribution of teachers' responses by block "Evaluation of procedural aspects of using fairy tales in STEM education"

Notes: author's own calculations

education significantly enhances critical thinking and collaborative interaction among students. At the same time, it was found that the reflective component of learning, involving awareness of one's own knowledge and assumptions, was the least developed. This necessitates improving methods for developing metacognitive and scientific analysis skills in relation to fairy-tale phenomena. Methodologically, it has been confirmed that the results are reliable when three mandatory steps are followed when working with a fairy tale: epistemic framing (making a clear distinction between artistic and scientific approaches), modelling (using schemes, models and

simple experiments) and reflecting on boundaries (identifying assumptions and limitations). These steps together prevent the emergence of pseudo-concepts and encourage scientific thinking in children. Thus, when integrated into the educational process, a fairy tale functions as an interdisciplinary cognitive tool that combines emotional and aesthetic impact with analytical activity. Its use contributes to the harmonious combination of the humanities and technology in education, the formation of students' research positions, and the development of scientific and technical literacy – the foundation of 21st-century education.

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