International Journal of Innovative Research and Scientific Studies, 8(3) 2025, pages: 558-567

IJIRSS
International Journal of Innovative Research & Scientific Studies

ISSN: 2617-6548

URL: www.ijirss.com

Visualizing cause-and-effect relationships in utilitarian educational processing in the course of "natural science"

Gulfat Kalelova[1], Bakhadurkhan Abdimanapov[2*], Aigul Damenova[3], Arman Demeuov[4], Dinara Sadirbekova[5]

[1]*Doctoral student of the Department of Ecology and Geography, Sarsen Amanzholov University, Ust-Kamenogorsk, Kazakhstan.*
[2]*Institute of Natural Sciences and Geography, Abai University, Almaty, Kazakhstan.*
[3]*Department of History and geography in education, Taraz University, Taraz, Kazakhstan.*
[4]*Department of Physical and Economic Geography, Department of Science, Eurasian National University, Astana, Kazakhstan.*
[5]*Postdoctoral fellow, Department of Science, Abai University, Almaty, Kazakhstan.*

Corresponding author: Bakhadurkhan Abdimanapov (*Email: sanat_kv@mail.ru*)

Abstract

This paper examines the pedagogical possibilities of using illustrative material to activate students' practice-oriented activities when studying complex relationships in nature. Theoretical analysis has shown that visual illustrative means, including graphs, diagrams, infographics, and interactive models, significantly reduce cognitive load, increase the level of material assimilation, and contribute to a deeper understanding of the processes being studied. For the first time, in this work, a model of receptive illustrative aesthetics (RIE) is postulated. This represents an innovative approach to the use of illustrative material. Within the framework of this model, illustrations cease to be static objects of information transfer and become dynamic means of meaning formation, in which the student acts as an active constructor of knowledge. The main mechanisms of the RIE model include semantic construction, modification of illustrations, and practical interpretation. The theoretical results of the study confirm that the use of RIE in the educational process contributes to the development of critical thinking, analytical skills, and cognitive flexibility of students. Particular attention is given to the prospects for introducing the model into natural science education, as well as to the issues of creating interactive educational platforms and digital tools that support visual modeling of complex processes. This work is a theoretical study based on the analysis of modern pedagogical, cognitive, and multimedia literature. In the future, empirically testing the RIE model and developing methodological recommendations for its implementation in the educational process are proposed.

Keywords: Cause-and-effect relationships, illustrative material, receptive illustrative aesthetics, science education, visualization.

DOI: 10.53894/ijirss.v8i3.6572
Funding: This study received no specific financial support.
History: Received: 14 March 2025 / **Revised:** 16 April 2025 / **Accepted:** 18 April 2025 / **Published:** 29 April 2025

Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: Conceptualization,G.K. and B.A; methodology,G.K. and B.A.; software, G.K. and A.D.; data curation, B.A., G.K. and D.S. writing – original draft preparation, B.A., G.K. and A.D., A.D., D.S.; writing – review and editing, B.A. and G.K.; supervision, B.A. All authors have read and agreed to the published version of the manuscript.

Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.
Publisher: Innovative Research Publishing

1. Introduction

Cause-and-effect relationships are obligatory attributes of scientific research and practical applications of science in general. The cause, effect, and connection between them are, in fact, what all sciences address, including natural sciences. This is the dominant and key goal of science. Depending on how a student perceives the importance, content, and meaning of cause-and-effect relationships, he can become a full-fledged natural scientist, an excellent teacher, or a very professional and qualified applied specialist. Therefore, cause-and-effect relationships are the most important and dominant element of natural science education, especially in the applied and practical sense.

This is why the dominant role in the universal educational course "Natural Science" is played by the actualization of cause-and-effect relationships. Understanding the correlations between cause and effect allows students to master complex concepts in natural phenomena more effectively and efficiently and apply them in real-world conditions. For example, in practical studies of biosystems or physical processes.

However, classical and traditional teaching methods based solely on the verbal presentation of information are often insufficiently effective. They do not consider the peculiarities of the cognitive processing of information and the multichannel perception of students.

In this context, we propose paying attention to the potential of illustrative content for visualizing cause–and–effect relationships with prospects for the utilitarian (practical) skills and competencies of students.

The use of illustrations in the educational process is based on the theory of dual coding, according to which information processing occurs through two information channels verbal and visual. Research in the field of cognitive psychology directly shows that combining text and graphic information improves understanding, reduces cognitive load, and promotes better assimilation of complex concepts [1, 2].

In particular, in the context of science education, illustrations such as diagrams, graphs, infographics, and interactive models allow students to visualize cause-and-effect relationships and predict outcomes and model processes [3, 4].

It is a priori obvious that the use of illustrative material contributes to the development of practice-oriented activities, including [5, 6]:

- And interactive modeling of processes (scientific simulations, animations);
- Creation of conceptual maps that display the relationships between phenomena;
- Working with infographics and graphical data analysis;
- Development of spatial, critical, creative and heuristic thinking through the analysis of visual representations.

Thus, in the context of developing research competencies, illustrative materials serve as certain mediators between purely theoretical knowledge and real scientific processes. Thus, students are encouraged to ask questions, test hypotheses and analyze experimental data.

Classical models of the perception of illustrations often view students as passive consumers of visual information, which limits their cognitive activity.

To overcome the passivity of the perception of illustrations, we consider and postulate the concept of receptive illustrative aesthetics (RIE), which is based on the development of ideas of active meaning-making, constructivism and cognitive flexibility.

Receptive illustrative aesthetics assume that the learner (student), who interacts with illustrations, does not simply perceive them but rather gives them a “real existence”, filling the voids between the image object and its interpretation. This is not a passive perception of visual content but an active construction of meaning through practical interpretation and comprehension of cause-and-effect relationships that are depicted or implied in illustrative materials.

Within the framework of our theoretical concept, we can emphasize several of its components:

- An illustration is not a static object but becomes a space for the student’s semantic activity;
- The student does not simply perceive but rather constructs the meaning of the illustration, giving it “real existence” through his own analysis, modification and interpretation;
- Interaction with the illustration is carried out in three stages: primary perception, such as the identification of key elements; analysis and reconstruction, such as the identification of new connections and interpretations; and practical modeling, such as the use of visual information for independent conclusions, hypotheses and forecasts.

Thus, within the framework of RIE, the learner is transformed into an active agent of cognition. This functional agency includes the use of visual means and illustrative content not only for memorizing information but also for independent research, searching for alternative interpretations, and building complex conceptual models. This approach is already much closer to perceiving the world in terms of causes and effects than simply the mnemonic and mechanical assimilation of natural science material.

Thus, the use of illustrative material in teaching natural sciences has significant pedagogical potential, promoting the activation of practice-oriented activities among students. However, traditional approaches to the perception of illustrations limit the possibilities of their use, interpreting visual means as passive elements of learning. Within the framework of receptive illustrative aesthetics, illustrations are considered dynamic objects of semantic activity that gain a "real existence"

in the process of interaction with them. This approach creates conditions for deep analytical work and develops students' abilities to independently form meaning, critical thinking, and practical research on complex natural science phenomena.

The concepts and theoretical approaches presented in this study provide a basis for further empirical study of the effectiveness of receptive illustrative aesthetics in pedagogy and the development of methodological recommendations for its practical implementation in the educational process.

Thus, we can propose a working hypothesis that visual illustrative patterns play a dominant role in activating the applied rethinking of cause–effect relationships in learners and students in the natural sciences. In this sense, we postulate an effective local paradigm of modern education: aesthetic illustrations act as a trigger for activating the understanding of cause–effect relationships in the natural sciences in utilitarian (practical) aspects.

2. Literature Review

Cognitive load theory Sweller [7] argues that visualization reduces the load on working memory, increasing the efficiency of information processing. According to this theory, illustrations allow for the redistribution of cognitive resources, which is especially important when complex relationships are studied in the natural sciences.

Paivio [8] research has shown that the simultaneous use of verbal and visual channels of information enhances memorization and learning. In the context of science education, illustrations allow students to understand the dynamics of processes and establish logical connections.

Mayer [9] proposed a model of multimedia learning, according to which the integration of illustrations and textual content creates an optimal learning environment. Educational research has shown that well-structured illustrations promote a deeper understanding of the material than text alone.

Nadolski et al. [10] developed a conceptual model of multiple representations learning (DeFT) in her work, which shows that graphs, charts, and animations enable learners to better grasp complex concepts.

Schnotz and Bannert [11] reported that combining multiple types of visual representations reduced cognitive load and promoted knowledge integration.

Bruner [12] emphasized the importance of actively involving learners in the educational process through research methods. In this context, the use of illustrations and visual models allows learners to independently identify patterns and construct hypotheses.

The concept of receptive illustrative aesthetics (RIA) that we propose is based on the principles of constructivism [13] and cultural-historical learning theory [14]. According to these approaches, students do not simply receive information but actively construct knowledge via illustrative material.

The concept of cognitive flexibility [15] confirms that dynamic and adaptive visual elements allow learners to explore alternative ways of understanding the material being studied.

3. Materials and Methods

This study is devoted to the analysis of pedagogical possibilities of using illustrative material to activate the practice-oriented activities of students when studying cause-and-effect relationships in the course "Natural Science." Particular attention is given to the development and postulation of a model of receptive illustrative aesthetics (RIE). This is an innovative approach to visual learning based on the idea of active meaning-making. Within this framework, the student becomes a designer of objective knowledge and a creator of subjective competencies through interaction with illustrative material.

The research methodology is based on the analysis of literary data and theoretical analysis, conceptual modeling, a systems approach and interdisciplinary methodological principles that combine the achievements of pedagogy, cognitive psychology, the theory of visual perception and multimedia learning.

The methodological tools used in this research are based on the interpretation and development of several key principles:

- The principle of constructivism, when knowledge is formed by the student in the process of his active interaction with the educational material;
- The principle of cognitive optimization, when visual illustrative means and content reduce the cognitive load and increase the efficiency of information assimilation;
- The principle of dual coding, when the integration of text and visual information activates both channels of perception, which improves memorization and comprehension of the material.
- The principle of active meaning-making, when the student does not simply perceive the illustration but creates its meaning through analysis, interpretation and modification.
- The principle of interdisciplinarity the research includes the analysis of data from pedagogy, cognitive psychology, multimedia learning and the theory of visual perception.

As a basic methodological aspect, we postulated the following null (working) hypothesis: the working hypothesis that visual illustrative patterns play a dominant role in activating the applied rethinking of cause-and-effect relationships in learners and students in the natural sciences. In this sense, we postulate an effective local paradigm of modern education: aesthetic illustrations act as a trigger for activating the understanding of cause-and-effect relationships in the natural sciences in utilitarian (practical) aspects.

To verify the null hypothesis, we postulated and analyzed a model of receptive illustrative aesthetics.

The idea behind the postulated model is that visual objects evoke an emotional response and facilitate deep comprehension of information. According to this concept, aesthetic perception influences cognitive processes, enhancing memorization and interest in the subject, and illustrations acquire semantic depth only in the process of their active analysis.

Within the framework of the comparative analysis, existing models of visual learning were studied, and their limitations were identified, which made it possible to substantiate the need to develop a new concept of RIE.

4. Results

Visual images are an integral part of educational processing, but their role is underestimated. In classical and traditional models of learning, illustrations are considered auxiliary tools that enhance verbal information. However, we argue that an illustration does not simply accompany a text but becomes an independent space for meaning formation, activating the cognitive and practical activity of the learner.

A comparative analysis of educational strategies and cognitive mechanisms confirms that illustrative content plays a decisive role in the formation of cause–effect relationships in students. In natural sciences such as physics, biology, chemistry, and ecology, complex processes and phenomena are difficult to explain via verbal methods alone. In this context, illustrations provide clarity, reduce cognitive load, and activate the integration of visual and textual processing channels.

The main pedagogical effects of using illustrative material in the classical version are interpreted through a number of criteria and attributes. Specifically, it facilitates the understanding of complex processes by presenting information in a graphical form. Through the stimulation of active thinking and meaning-making, the student establishes connections between objects and not just memorizes individual facts. Through the development of research skills, visual models, graphs and interactive illustrations can be created.

However, classical and traditional approaches to the use of illustrations remain linear and static, treating visual material as a supplement to the text. This paper proposes a model of receptive illustrative aesthetics (RIE), which allows us to rethink the role of illustrations in the educational process and turn them into active objects of meaning-making.

The model of receptive illustrative aesthetics (RIE) is a conceptual system in which illustration becomes an interactive environment for active comprehension and construction of knowledge. The main postulate of the model is that an illustration is not a passive object but receives a "real existence" only in the process of active interaction with it by the learner. The learner, as an active interpreter, constructs the meaning of the illustration, forming cause-and-effect relationships through practical interpretation.

The RIE is built on three key elements:

1. Illustration as a field of semantic activity.

In traditional teaching, illustrations serve as an auxiliary means to reinforce the text. In the context of RIE, an illustration is a dynamic semantic space in which the student independently forms connections between elements:

The visual object is interpreted not as a static image but as a knowledge constructor that changes depending on the context, previous experience and learning objectives.

2. Active agent - learning

In the RIE model, the learner is not a passive consumer of knowledge but becomes a constructor of meaning, independently identifying patterns and establishing connections between elements of visual information.

This process goes beyond traditional knowledge transfer, turning learning into interactive exploration.

3. Process of practical interpretation.

The interpretation of illustrations occurs not through direct perception but through analytical comprehension, restructuring, and integration with other knowledge.

Practical interpretation involves the student changing the illustration, adding new elements and actively modeling the processes.

In RIE, we identify the following key mechanisms of the model:

1. The mechanism of semantic construction

At this stage, the student analyzes the illustration, identifying key elements and their relationships. The semantic structure of the image is deconstructed and rebuilt.

Example: analysis of the illustration "The water cycle in nature" - the student does not just study the diagram but models scenarios of changes (for example, the impact of global warming).

2. Mechanism of modification and reconstruction

The learner actively intervenes in the visual content, correcting, changing and refining it. This process may include creating new diagrams on the basis of basic illustrations, developing visual material, adding new elements and expanding the system of relationships.

Interactive interaction with the illustration (for example, using AR/VR technologies).

3. Mechanism of practical modeling

In this phase, the student tests hypotheses and analyzes cause–and–effect relationships. This is done via virtual laboratories where parameters can be changed and the consequences observed and via graphical simulations that allow experimentation with variables (for example, modeling the movement of tectonic plates).

Therefore, let us summarize the results.

In the proposed theory and model of receptive illustrative aesthetics (RIE), illustrations are considered not as passive carriers of knowledge but as dynamic objects that receive "real existence" only in the process of active interaction with them.

Here, the student becomes not just a consumer (recipient) of educational content but also an interpreter and constructor of knowledge, identifying cause–and–effect relationships through analysis, modification and expansion of visual materials on the basis of their own mental constructs.

The RIE model is based on active reception, where the meaning is not "installed" by the author of the illustration but is constructed by the student depending on his knowledge, experience, context and research goals. This allows us to overcome the linear perception of information and create a multilayered educational environment in which illustrations become not static images but active mediators of meanings.

Thus, the key result of the study is the creation and postulation of a model of the RIE, which includes the following stages:

1. Primary reception: The learner perceives the illustration as a potential semantic object that does not have a fixed meaning.

2. Analysis and Reconstruction: The student analyzes the visual elements, identifies key relationships, and begins to "bring life" to the illustration by adding their own interpretations.

3. Practical interpretation: Through active interaction with the illustration (modification, creation of own diagrams, experimentation with parameters), the student constructs a new meaning that reflects his personal experience and knowledge.

4. Integration: The acquired knowledge is integrated with textual and theoretical materials, which allows for the formation of a holistic understanding of cause–effect relationships.

That is, the model is based on the synthesis of constructivist principles, dual coding theory, and multimedia learning and is an innovative approach to visual learning. The RIE model promotes the transition from the passive perception of illustrations to their active use as tools for meaning-making and practical research.

In classical pedagogy, an illustration is considered a fixed object that carries an unambiguous interpretation. However, in RIE, it acquires meaning only in the act of reception. An illustration is a potential semantic object that exists in a "latent" state until its comprehension and interpretation by the student [16].

In our work, we distinguish the following forms of illustrative content:

Table 1.
Types of illustrative content and their role in the educational process.

Type of illustrative content	Functions in educational processing	Examples of use
Graphs and charts	Identifying dependencies between variables	O_2 concentration and global temperature
Process flow charts	Demonstration of the dynamics of phenomena	Water cycle diagram in nature
Infographics	Comprehensive presentation of information in a concise form	Infographics "Ecosystem Structure"
3D models and animation	Visualization of complex spatial interactions	Animation of the movement of lithospheric plates
Virtual laboratories	Conducting experiments without physical contact	Modeling chemical reactions in a digital environment

To perceive an illustration as an unchanging information carrier, the learner models its meaning based on his own cognitive experience and practical interaction. This is the process of "interactive semantic construction," during which a static image becomes a field of cognitive activity.

Traditional causality schemes assume rigid predetermined Ness. That is, fact A leads to fact B. In RIE, cause–and–effect relationships are perceived as multivariant and can be reconstructed by the student depending on the depth of the analysis, the posing of new questions and the change in context.

Thus, the visually illustrated object in the RIE model does not close in on itself but stimulates the student to actively interact. This interaction is interpreted through three active attributes:

- And analysis, within the boundaries of which the student examines the structure of the image, identifies key elements and connections,
- Modification, when, on the basis of the analysis, the student supplements the illustration, creating new connections and clarifying the meaning,
- Expansion, when illustrative content is included in a broader context, forming a multilayered interpretation on the part of the learner.

Thus, the RIE model is built on the interaction of three dominant elements:

- And illustration as a carrier of potential knowledge, which does not have a fixed meaning until the moment of interaction,
- With the student as an active agent who interprets, modifies and constructs the meaning of a visual object,
- Context as external and internal factors influencing perception (previous experience, level of knowledge, research goals, emotional state),
- Accordingly, we believe that the process of reception within the framework of the RIE should go through three key stages:
- Primary perception, when the learner encounters a visual object and perceives it as a static image,

- And analysis and interpretation, when the student begins to comprehend the illustration, identify elements, highlight connections and ask questions.
- To construct and implement meaning. When a student modifies an illustration, it expands its meaning, adds details and builds a new conceptual model.

Thus, we conclude that RIE allows us to reconsider the role of illustrations in science-oriented education, turning them into tools for active research. In particular, instead of fixed RIE schemes, we propose interactive modeling, where the student himself or herself constructs connections:

- In a virtual laboratory, changing parameters leads to different consequences, allowing the student to experiment with causality.
- And analysis of infographics: the student receives fragments of information and builds a logical chain himself,
- Expanding the boundaries of visual experience through multimodal technologies

We believe that RIE works particularly effectively in combination with interactive and immersive environments (VR, AR, simulations), in which the learner:

- Can change image parameters and observe the transformation of data,
- To construct variable scenarios, explore the multivariance of cause–and–effect relationships,
- Create your own visual interpretations, transferring knowledge into practical applications.

To achieve the maximum effect from using illustrations in interactive and immersive environments in science education, we suggest the need to consider the following methodological principles of their integration:

Table 2.
Learning methods using visual data

Method	Description	Example of application
Problem-based learning method	Creating learning situations that require visual data analysis	Identifying factors influencing biodiversity using an ecosystem map
Research method	Hypothesis formulation, experimental testing and modeling	Using 3D models to study seismic wave propagation
Visual argumentation method	Image analysis and logical inference	Interpreting climate change using satellite images
Project method	Creation of students' own illustrative materials	Developing infographics about the carbon cycle

Thus, the theory of RIE that we postulate offers a radical revolutionary rethinking of the role of illustration in education. Within the framework of which the use of visual illustrative content in an aesthetic form acquires the following new definitions:

- And illustrations receive “real existence” only at the moment of active interpretation by the student,
- The learner becomes a constructor of knowledge and not a passive consumer of visual illustrative content,
- Cause–and–effect relationships are considered dynamic structures, not rigid patterns,
- Learning becomes a process of practical interaction with visual objects, allowing for a deeper understanding and development of research competencies.

Thus, RIE creates a new educational environment in which knowledge is born in an interactive and creative dialogue between the learner and the image. This opens up broad prospects for the use of interactive technologies, multimedia resources, and cognitive strategies, making learning more meaningful, exciting, and effective.

5. Discussion

The entire education system is built not only on semantics but also on visual images. In this scheme, the subjects of education are teachers and students, the objects of education are knowledge and meaning, and visual images and illustrations program the knowledge being transmitted for effective perception and further internal analysis.

This is why the use of illustrative material in teaching the natural sciences plays a dominant role in forming students’ holistic and syncretic understanding of complex natural cause-and-effect processes and phenomena. It is obvious that visual images such as diagrams, charts, infographics, and multimedia animations not only facilitate the perception of information but also contribute to the activation of cognitive processes, the development of research skills, and critical thinking. This is especially relevant in natural science education, where the study of complex systems requires the presentation of multidimensional relationships, for example, in ecology, physics, or biology.

However, traditional and classical methods and techniques of using illustrative material usually assume passive perception, where images serve only as reinforcements and ordinary visualizations of text content. This approach clearly limits the active cognitive activity of students, leaving them with the roles of consumers (recipients) of information and not its analyzers, interpreters, or even creators. In this context, a fundamentally new approach is the concept of receptive illustrative aesthetics (RIE), which illustrates a dynamic role as an object of meaning-making.

Receptive illustrative aesthetics as a pedagogical strategy is based on the idea that an illustration does not contain a fixed meaning but receives “real existence” only in the process of active interaction of the learner with it [17]. Thus, the meaning, patterns and content of the illustration are constructed and not passively perceived.

Thus, the key principles of RIE include the following attributes:

- An illustration is a field of semantic activity in which the learner actively reconstructs visual information, analyzes its structure and adapts it to his understanding.
- When the student is an active interpreter, instead of memorizing information, the student becomes a participant in the learning process, interacting with illustrations and changing and interpreting them.
- A process of interactive interpretation, where the meaning of illustrations is formed through interaction with context, experiments, empirical observations and previous knowledge.

Receptive illustrative aesthetics combines aesthetic principles and constructivist ideas, transforming the process of perception into active meaning-making. The student not only perceives the image but also asks questions, analyzes its components, connects them with existing knowledge and, thus, reconstructs cause-and-effect relationships. This allows the student to develop critical thinking and the ability to independently research, which is important for practice-oriented learning in the natural sciences.

That is, RIE allows going beyond the boundaries of the traditional and classical paradigm of visual learning, within which the student simply "sees" the image but does not actively analyze it. Illustrations in the learning process should activate not only the eye and mnemonic apparatus of the student but also the analytical apparatus of understanding and interpreting the mechanically assimilated and creatively processed content. Moreover, this is necessary for the development of the utilitarian (practical) skills of students.

In natural science education, the dominant problem and task is to understand the relationships between natural phenomena. Cause–and–effect relationships are the foundation of natural science, and they form the basis for understanding natural processes. For example, these include the hydrological cycle, climate change, photosynthesis, and the movement of tectonic plates.

In the context of the natural science course, illustrations allow us not only to see how cause–effect relationships work but also to actively participate in their analysis and reconstruction. This is especially important, since understanding these relationships requires students not only to know the facts but also to be able to see the logic of processes and events. Visual aids, such as interactive models, graphs, and animations, create an opportunity for students to experiment with parameters and observe how changes in one factor affect others. These findings can be used to activate research activities and help to deepen the understanding of natural phenomena.

Thus, once again, we note that illustrations in the learning process become not only an explanatory tool but also a mechanism for actively involving students in the process of constructing knowledge. In this context, it is important to note that the interactivity of illustrations (for example, the ability to manipulate model parameters or observe the effects of changing factors) is a powerful tool for activating practice-oriented learning, allowing students to implement hypotheses, test them in practice, and model various scenarios.

The RIE model assumes that illustrations become a tool for active meaning-making, where the learner not only perceives but also actively constructs the meaning of the image. This process includes not only passive perception of data but also modification of the illustration, as well as reorganization of its elements in accordance with one's own understanding of the material being studied. The RIE model takes illustrations beyond static objects and turns them into dynamic tools for cognition, which significantly increases their potential for active learning and development, returning to what has already been said, critical thinking.

Theoretically, RIE allows the synthesis of two important aspects of visual perception: the aesthetic value of an illustration and its pedagogical significance. According to the views of aestheticians, visual objects have the ability to evoke not only emotional responses but also immerse one in the process of deep interpretation, stimulating cognitive activity. In a pedagogical context, this means that the aesthetic characteristics of an illustration, such as composition, color palette, and harmony of forms, can increase the learner's interest, making the process of acquiring knowledge more engaging and emotionally rich.

Thus, RIE activates not only cognitive but also emotional aspects of perception, which contributes to a deeper and more multilayered understanding of the material being studied.

To summarize, in this context, the use of RIE allows the following:

- Transform illustrations from static objects into dynamic means of understanding,
- To develop and activate the actual and potential ability of students to analyze relationships by changing the parameters of illustrations (for example, adding new relationships between elements of the diagram),
- To make the process of studying cause–and–effect relationships personalized, as each interpretation of the illustration becomes unique.

For example, the typical water cycle in nature is a fixed sequence of processes (evaporation → condensation → precipitation infiltration). In the context of RIE, the student models the following scenarios: what happens when the temperature changes, how does a change in vegetation affect evaporation, and what will be the effect when the atmospheric pressure changes?

There is no doubt that such a "closed" approach effectively promotes the development of analytical and research skills, allowing students to not only remember but also understand and predict. That is, to develop not only critical but also heuristic thinking.

Modern digital technologies, including virtual reality (VR) and augmented reality (AR), make it possible to introduce the concept of RIE into the educational process, making illustrations dynamic and interactive.

Illustrative examples of the integration of RIE into the educational process include the following:

- And interactive simulations, where learners can influence variables in the system (for example, changing the temperature in a climate change model).
- Augmented reality (AR), which allows animated layers to be superimposed on static images, turning them into interactive models;
- Digital concept maps when students create individual structures of relationships between elements of the processes being studied.

The use of such technologies significantly expands pedagogical possibilities, allowing students to experiment with visual data and actively interact with it.

On the basis of the above, we can theoretically and logically conclude that the use of RIE clearly contributes to the development of key educational competencies of the 21st century, such as the following:

- Critical thinking, when students not only absorb information but also analyze it, draw conclusions and compare different scenarios;
- And research competencies, within the framework of which the RIE model assumes that students can independently change the parameters of illustrations, creating their own hypotheses and testing them,
- Systemic thinking, when learning based on RIE allows students to see a holistic picture of the relationships in nature, which contributes to the development of multidimensional analysis skills;
- Heuristic thinking, when students gain the ability and skills to predict events and processes on the basis of the analysis of causes, effects and their correlation consequences.

Thus, illustrative material within the framework of the RIE ceases to be an informational object and becomes a means of cognition in which students play an active role.

Thus, the process of integrating receptive illustrative aesthetics into natural science education can be implemented through modeling natural processes, using interactive simulators, and creating conceptual maps that students can adapt further, creating their own picture of the connections between elements of the scientific discipline. This creates conditions for more flexible acquisition of the material, since each student can interpret the illustration in their own way on the basis of their personal knowledge and experience.

At the same time, interactive technologies (e.g., virtual reality, augmented reality, computer simulations) are becoming key elements in the implementation of RIE. The use of these technologies not only enhances the visualization of cause–and–effect relationships but also gives students the opportunity to interact with processes in real time, varying parameters and simulating changes. Students can not only analyze data but also intervene in the system, observing how their actions affect the development of processes. This contributes to the development of practical skills in the context of natural science education and allows students to construct cause-and-effect relationships on the basis of direct interaction with the material.

In general, the proposed concept of receptive illustrative aesthetics represents an innovative approach to the use of illustrative material in pedagogy, allowing students not only to study illustrations but also to construct their meaning, revealing new cause–and–effect relationships.

The use of RIE in natural science education opens new prospects for a deep understanding of the interrelations of natural phenomena and promotes the development of analytical thinking and research competencies.

6. Conclusion

Thus, the aim of our study was a theoretical analysis and conceptual interpretation of the pedagogical possibilities of using illustrative material to activate students' practice-oriented activities when studying cause-and-effect relationships in the course "Natural Science." We confirm that illustrative materials, including diagrams, graphs, charts, infographics, and multimedia animations, play an effective and efficient role in forming a holistic understanding of the causes and effects of natural processes and contribute to a deep understanding of the relationships between phenomena.

We can reliably state that visual tools reduce the cognitive load and activate dual coding processes. This allows students to more effectively assimilate complex concepts and ideas related to cause-and-effect relationships. Illustrative material definitely contributes to the progressive development and activation of research skills. Especially in applied aspects. Students can analyze, compare and model the studied real processes and make predictions about possible changes in systemic interactions in nature. These definitions are often utilitarian (practical) in nature.

However, traditional approaches to the use of illustrations are often limited to their passive or inert perception. Naturally, this circumstance somewhat limits the potential of visual thinking for meaningful learning. Therefore, it is necessary to look for new theoretical approaches, schemes and models to intensify progress and activate the intellectual perceptions of pedagogical material. This is especially the case in complex areas, such as the cause–and–effect relationships of phenomena in the natural sciences.

Accordingly, we postulated and introduced a new model of local learning receptive illustrative aesthetics. In the context of this model paradigm, the learner becomes not just a contemplator and recipient of practical knowledge about cause–effect relationships. However, they are an active agent of educational processing. Through modification, analysis, and practical interpretation of visual content, one can independently identify and build cause–effect relationships. That is, we integrated agency into the learning process as an important aspect of interaction and relationships. Thus, the learner becomes an active agent of cognition, giving illustrations of “real existence” through the modification and analysis of visual data, which in turn contributes to a deeper understanding of the material.

We view illustrative material not as a static image or pattern but as a dynamic tool that should activate the process of internal meaning formation in the learner. That is, our task is not just to transfer knowledge. However, it also initiates the

process of the formation of response meanings to initiate the processes of analysis and synthesis in the learner. That is, we are interested not only in the assimilation of knowledge but also in the reaction to new knowledge when the learner adapts visual information to his own level of understanding and knowledge.

All this can be effectively accomplished through interactive dialog, in which the learner constructs new ideas and understandings in contact with visual illustrative images, patterns and elements.

Illustrative material at a sufficiently high level of aesthetics enhances the role of the original educational content in cause–and–effect relationships. In addition, the development of critical thinking and research motivation of the student is initiated. This approach harmoniously combines aesthetic principles associated with the perception of visual images with the pedagogical function of illustrations as a means of active learning and knowledge construction.

In addition, this approach encourages individualization of the educational process, as each student can interpret the illustrations in the context of their personal experience and level of preparation. This creates conditions for more personalized learning, in which attention is given not only to the actual content but also to meta-subject competencies, such as the ability to analyze, interpret and apply knowledge.

Thus, our model of receptive illustrative aesthetics expands educational horizons and transforms traditional approaches to teaching the natural sciences. This approach is based on the dominant use of illustration as an interactive mechanism for exploring cause–effect relationships.

Each student perceives the illustrations in their own way, in accordance with their ideas and type of thinking. This emphasizes the adaptive nature of the illustrations from the point of view of individual perception. Changing the parameters and dynamics of the illustrations allows students to model cause-and-effect processes and relationships in nature or in a certain system during interactivity. This additionally activates constructive and creative thinking in students, allowing them to more confidently create new ideas, meanings, and hypotheses about cause-and-effect relationships.

The proposed model of receptive illustrative aesthetics requires further development through the creation of special interactive educational platforms with high-quality, informative and aesthetic illustrative content. It is also important to develop a full-fledged methodological base for various training options in the context of the "Natural Science" course in the systems and structures of secondary and higher education. Moreover, further experimental and theoretical studies of the influence of illustrative material on the effectiveness and quality of education in the notation of receptive illustrative aesthetics are needed.

Thus, the results of the theoretical study show that illustrative material, especially of an aesthetic nature, is an effective and efficient tool for activating and developing students' practice-oriented activities. The proposed model of receptive illustrative aesthetics (RIE) opens new real and potential opportunities and prospects for using visual means in the educational process.

Overall, RIE is an innovative pedagogical tool that facilitates deep, meaningful interaction between students and illustrations, which ultimately leads to increased effectiveness in natural science education and the development of research competencies in students. The prospects for the development of the RIE model lie in the practical implementation of this concept in real educational programs, which will require the development of methodological recommendations for the use of various types of illustrative material in the learning process. In particular, creating digital platforms for interactive modeling, as well as educational tools for creating illustrations that students can adapt and modify depending on the context, is necessary. It is also important to continue empirical research to assess the impact of RIE on learning outcomes and the development of key competencies, such as critical thinking and scientific research skills.

Thus, the use of illustrative material in the context of receptive illustrative aesthetics opens new horizons in pedagogical practice, transforming students from passive recipients of information into active agents in the process of creating knowledge, which is important for modern education and the formation of 21st century competencies.

References

[1] B. Abdimanapov, S. Kumarbekuly, and I. Gaisin, "Technology for achieving learning objectives through a system-activity approach and the development of critical thinking in geography studies," *Journal of Ecohumanism*, vol. 3, no. 8, pp. 11989–12003, 2024. https://doi.org/10.62754/joe.v3i8.5797

[2] U. Nurbol, Z. Kairat, A. Bakhadurkhan, M. Marat, T. Kenjekey, and M. Ussenova, "Students' views on the use of technology in geography course," *International Journal of Emerging Technologies in Learning*, vol. 15, no. 23, pp. 42-51, 2020. https://doi.org/10.3991/ijet.v15i23.18781

[3] S. U. Laiskhanov, "A study of the effects of soil salinity on the growth and development of Maize (Zea Mays L.) by using Sentinel-2 Imagery," *OnLine Journal of Biological Sciences*, vol. 22, no. 3, pp. 323–332, 2022. https://doi.org/10.3844/ojbsci.2022.323.332

[4] K. Sanat, U. Nurbol, A. Bakhadurkhan, S. Anargul, D. Zukhra, and K. Gulfat, "Teachers' opinions about technological pedagogical content knowledge used in geography lessons," *World Journal on Educational Technology Current Issues*, vol. 14, no. 4, pp. 1217–1224, 2022. https://doi.org/10.18844/wjet.v14i4.7731

[5] S. Manapova, B. Shaikhova, S. Kumarbekuly, I. Mikushina, and I. Afanasenkova, "A set of online tools for teaching chemistry considering a systematic approach to the educational process," *International Journal of Innovative Research and Scientific Studies*, vol. 8, no. 1, pp. 1363-1379, 2025. https://doi.org/10.53894/ijirss.v8i1.4613

[6] U. Nurbol, L. Shakhislam, K. Kulyash, A. Bakhadurkhan, K. Sholpan, and Z. Kairat, "Evaluation of students' views on teaching the subject of migration through distance education in Kazakhstan geography course," *World Journal on Educational Technology: Current Issues*, vol. 14, no. 1, pp. 294-305, 2022. https://doi.org/10.18844/wjet.v14i1.6260

[7] J. Sweller, "Load during problem solving: Effects on learning," *Cognitive Science*, vol. 12, no. 2, pp. 257–285, 1988. https://doi.org/10.1207/s15516709cog1202_4

[8] A. Paivio, *Mental representations: A dual coding approach*. USA: Oxford University Press, 1990.

[9] R. E. Mayer, *Multimedia learning*, 3rd ed. UK: Cambridge University Press, 2021.
[10] R. J. Nadolski, P. A. Kirschner, and J. J. van Merriënboer, "Process support in learning tasks for acquiring complex cognitive skills in the domain of law," *Learning and Instruction*, vol. 16, no. 3, pp. 266-278, 2006. https://doi.org/10.1016/j.learninstruc.2006.03.004
[11] W. Schnotz and M. Bannert, "Construction and interference in learning from multiple representation," *Learning and Instruction*, vol. 13, no. 2, pp. 141-156, 2003. https://doi.org/10.1016/S0959-4752(02)00017-8
[12] J. S. Bruner, *Toward a theory of instruction*. USA: Harvard University Press, 1974.
[13] J. Piaget and E. Duckworth, "Genetic epistemology," *American Behavioral Scientist*, vol. 13, no. 3, pp. 459-480, 1970. https://doi.org/10.1177/000276427001300320
[14] L. S. Vygotsky and M. Cole, *Mind in society: Development of higher psychological processes*. USA: Harvard University Press, 1978.
[15] K. A. Ericsson and W. Kintsch, "Long-term working memory," *Psychological Review*, vol. 102, no. 2, pp. 211–245, 1995. https://doi.org/10.1037/0033-295X.102.2.211
[16] R. Budiu and J. R. Anderson, "Interpretation-based processing: A unified theory of semantic sentence comprehension," *Cognitive Science*, vol. 28, no. 1, pp. 1-44, 2004. https://doi.org/10.1207/s15516709cog2801_1
[17] M. Grunwald, *Human haptic perception: Basics and applications*. Germany: Springer Science & Business Media, 2008.