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**DEVELOPMENT AND APPLICATION OF MODERN
CONSTRUCTIVIST CONCEPTS IN PHYSICS TEACHING**

532.02 School Didactics (Physics)

Summary of the Doctoral Thesis in Educational Sciences

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CONCEPTUAL FRAMEWORK OF THE RESEARCH

Relevance and importance of the research topic. At the international level, physics teaching is going through a systematically documented conceptual crisis. The PISA 2025 science assessment framework explicitly defines scientific competence through the student's ability to explain phenomena from a conceptual perspective, to evaluate and design scientific investigations, and to interpret data and evidence [53], precisely the dimensions in which students record, year after year, the weakest results. The decline of interest in physics is empirically documented on both sides of the Atlantic: White, Chu and Oman [63], following a national survey conducted in American high schools during the 2023–2024 school year, confirm a steady decrease in the number of students choosing physics, while Nikaj et al. [51], in a comparative study carried out over twenty years in universities in Albania and the rest of Europe, attest the same downward trend at the university level. This contraction of interest in physics occurs despite the growing demand for STEM specialists on the labour market [30]. The Republic of Moldova is no exception to this trend, the causes lying not in the intrinsic difficulty of the subject but, above all, in the way physics continues to be taught in most classrooms.

The economy of the 21st century places demands on educational systems that are fundamentally different from those of previous eras: employers in technological and innovative sectors no longer seek graduates capable of reproducing information, but people who know how to solve complex problems, collaborate effectively in interdisciplinary teams and think critically. The Council of the European Union Recommendation on key competences for lifelong learning explicitly places creativity, critical thinking and learning autonomy at the centre of educational outcomes [25], a direction also taken up by the OECD Learning Compass 2030 framework, which redefines educational success through the student's ability to transform knowledge into responsible action [52]. The Council of the European Union Resolution on the European Education Area 2021–2030 enshrines the development of the capacity for continuous learning as one of the strategic priorities of the decade [26] — a priority imposed by an empirically confirmed reality: the analysis of twenty years of lifelong learning policies carried out by Ceschi et al. [23] shows that, as knowledge acquired in school becomes obsolete ever more rapidly, the capacity to reconfigure competences becomes an essential condition for employability and social inclusion.

The educational system of the Republic of Moldova is undergoing a continuous process of curricular reform, oriented towards competences and aligned with European standards. The

new Concept of the subject “Physics. Astronomy” [49] marks a clear shift from teaching based on the transmission of knowledge towards student-centred teaching, yet the constructivist orientation remains present only at the conceptual level: didactic strategies of proven effectiveness, such as the 5E model, IBSE, the Flipped Classroom or the jigsaw method, are not explicitly mentioned. The present research responds directly to this need, providing the theoretical grounding, the concrete models of lesson organisation and the empirical evidence necessary to give real substance to the reform at the level of the everyday lesson.

Description of the situation in the research field. From a theoretical perspective, constructivism represents one of the major paradigms of contemporary pedagogy, grounded in research from cognitive psychology, neuroscience and science didactics. Its foundations, developed by Piaget, Vygotsky, Bruner and von Glasersfeld, have been progressively refined and operationalised, and today constitute the dominant frame of reference in curriculum design and teacher training at the international level.

The international research community in the field of science teaching (*Science Education*) has accumulated, over the last three decades, a substantial body of empirical evidence in favour of constructivist approaches. Hattie’s meta-analytic synthesis [41], based on more than 800 meta-analyses of the factors influencing school achievement, placed among the most effective practices precisely those strategies centred on the student’s active cognitive engagement rather than on the direct transmission of information. In the same direction, Harlen [39] formulated the fundamental principles of modern science education, oriented towards the progressive construction of conceptual understanding. Analysing research in physics didactics specifically, McDermott [47] showed that progress in the discipline depends directly on identifying and correcting students’ misconceptions through active teaching methods, while Redish, Saul and Steinberg [56] demonstrated experimentally that laboratories based on active engagement significantly increase the effectiveness of physics learning compared with traditional demonstration experiments. Meltzer and Thornton [48], synthesising two decades of research on active learning instruction, consistently confirmed the superiority of these methods over frontal teaching. This direction is also supported by more recent research: Uwamahoro et al. [61] and Banda and Nzabahimana [3] showed that the level of students’ conceptual understanding in physics is directly proportional to the frequency and quality of laboratory use, especially when real experiments are combined with digital simulations.

In the Romanian pedagogical space, constructivist principles are increasingly present in curricular and methodological discourse. Elena Joița laid the psycho-pedagogical foundations of student-centred instruction [44]; Liliana Ciascai promoted the principle of the active

construction of knowledge through one's own experience and collaboration [24]; Constantin Cuciş emphasised that the student does not passively receive knowledge but constructs it through experience and personal effort [55]; and Sorin Cristea operationalised constructivism in the concept of education for transformation [27]. In the Republic of Moldova, Ludmila Franţuzan developed the concept of transformative learning, close to constructivist principles [33]; Ion Botgros operationalised constructivism methodologically for the physics lesson, emphasising problematisation and cognitive conflict [9]; Mihail Calalb extended this direction towards physics didactics [14]; and Viorel Bocancea complemented it, highlighting the role of research and experiment in the active construction of knowledge [7]. Nevertheless, the application of constructivism to physics teaching remains insufficiently systematised at the level of a model that correlates the theoretical foundations with the concrete organisation of the teaching process [11; 65].

The analysis of the situation in the field of constructivist physics didactics reveals the following contradictions:

- between international research evidence, which confirms the superiority of constructivist methods over traditional teaching, and the actual practice of physics teaching, which has remained centred on the transmission of knowledge;
- between the reforming intention of current curricular documents, oriented towards student-centred teaching, and the lack of explicit methodological guidelines, strategies such as the 5E model, IBSE, the Flipped Classroom or the jigsaw method not being mentioned as such;
- between the epistemic coherence of the curricular framework, which refers to authentic processes of scientific inquiry, and the absence of a clear procedural didactic model, the teacher being conceptually repositioned as a facilitator but without a stable model to support this role;
- between the epistemic specificity of modern physics content, which requires a constructivist approach of modelling and interpretation, and the persistence of traditional teaching based on the transmission of definitions and formulas.

The research problem consists in the need to establish to what extent a constructivist organisation of physics learning, centred on the student's cognitive effort, on the use of prior knowledge and on the development of metacognition, can lead to deeper conceptual understanding and higher academic results, given that traditional teaching does not sufficiently capitalise on these mechanisms.

The object of the research is the didactic process of physics learning within the lesson, analysed through the lens of the application of constructivist teaching strategies.

The aim of the research is to determine the theoretical, methodological and didactic premises of organising constructivist physics learning.

Objectives of the thesis

1. Analysis of the theoretical and didactic foundations of constructivism in physics teaching, by highlighting the cognitive mechanisms involved in active learning, the role of feedback and the relationship between educational paradigms and forms of teaching.
2. Modelling and ranking of educational paradigms according to their effect on learning, by building a scale that highlights the transition from learning by doing to learning through the assumption of cognitive objectives, with differentiated impact values.
3. Methodological design of the physics lesson based on constructivist principles, by integrating the 5E model and laboratory activity organised as a process of scientific research, with emphasis on investigation, collaboration and reflection.
4. Empirical validation of the impact of constructivist organisation on student performance, by correlating laboratory activity and didactic strategies with academic results, using statistical analyses and highlighting the consistency of results at different school levels.
5. Examination of how constructivism functions within the curricular framework and identification of the limits of its application, by analysing the distribution of constructivist dimensions across the Concept, the Curriculum and the Guide and by highlighting the differentiated losses in the implementation process.
6. Exploration of the epistemic specificity of modern physics content and its implications for understanding, by investigating how phenomena inaccessible to direct observation require modelling, the interpretation of relationships and the integration of fundamental concepts into complex explanations.

Research hypothesis

The integration of constructivist principles into physics teaching, through an organisation centred on student activity, constant feedback and the development of metacognition, has the potential to radically transform the learning process, leading to deeper conceptual understanding and higher academic results. It is considered that students' progress is achieved not through the passive reception of knowledge, but through their active involvement in investigation, explanation and the confrontation of ideas, which gives the physics lesson a lively, dynamic and creative character. The empirical validation of this hypothesis is expected to confirm the existence of strong correlations between the way learning is organised and the performance achieved, demonstrating that the constructivist approach is

not merely a methodological option but an essential condition for forming authentic understanding in modern physics.

The synthesis of the research methodology is based on three types of methods: grounding, or theoretical, methods, used to document and systematise constructivist concepts; application, or empirical, methods, materialised in the pedagogical experiment, observations and studies carried out under real teaching conditions, with analysis of students' academic results; validation, or statistical, methods, used to compare results between groups, analyse student progress and examine the relationships between the investigated variables.

The scientific novelty and originality of the research consist in:

1. Proposing and grounding the scale of constructivist educational paradigms, which ranks, according to effect size, the process of physics learning in three progressive steps: active learning, learning through understanding, and learning through the assumption of cognitive objectives.
2. Formulating the operational triad of constructivist physics learning, grounded in the interdependence between the student's cognitive effort, the use of prior knowledge and metacognition, complemented by the establishment of feedback as the central mechanism for regulating learning.
3. The didactic operationalisation of constructivism in the physics lesson, by correlating the teacher's actions with students' cognitive processes within didactic strategies based on research, interaction and reflection.
4. The empirical validation of the application of constructivist strategies in physics teaching, by analysing the relationship between the organisation of learning and student performance and highlighting the role of the teacher as a facilitator of learning.
5. Grounding the didactic specificity of teaching modern physics content, by characterising the way knowledge is constructed on the basis of modelling, the interpretation of phenomena and the establishment of physical relationships.
6. Highlighting the dynamics of the transposition of constructivist dimensions, namely the status of the student, the construction of knowledge, interaction and the role of the teacher, in physics curricular documents, by analysing their transformation from the conceptual level to the structural and operational level.

The theoretical significance of the research consists in grounding an evolutionary perspective on constructivist paradigms in physics teaching, in deepening the role of conceptual understanding, cognitive effort, metacognition and feedback in constructivist physics learning, as well as in integrating models of learning through research, investigation and reflection into

a unified constructivist conception of the physics lesson. The research also contributes to interpreting the physics lesson and laboratory as epistemic spaces of investigation, argumentation and collective construction of scientific meaning, highlighting the relationship between experimental activity and academic performance in physics learning.

The applied value of the research consists in developing a framework for analysing constructivist principles in physics curricular documents, applicable in the evaluation and design of the school curriculum, as well as in developing methodological guidelines for the constructivist organisation of the physics lesson and laboratory, by integrating investigation, reflection and experimental activity into the learning process. The research provides empirical validation for the application of constructivist approaches and highlights the relationship between experimental activity and academic performance in physics, while also capitalising on modelling and conceptual representations in teaching contemporary physics topics such as black holes and gravitational waves.

Approval of the research results was achieved through presentations at national and international scientific conferences, at meetings of the Republican Methodological Seminar of physics teachers, and through scientific articles published in national and international journals.

Publications on the thesis topic. The research results are reflected in 10 scientific papers, of which: 1 article in a recognised international journal, 3 articles in journals included in the National Register of specialised journals, and 6 articles in the proceedings of international scientific conferences held in the Republic of Moldova.

Structure of the thesis: introduction, three chapters, general conclusions and recommendations, 140 pages of main text, a bibliography of 214 sources, a list of abbreviations, 13 appendices, 31 tables and 18 figures.

CONTENT OF THE THESIS

The Introduction presents the relevance of the topic in the context of the educational requirements of the 21st century, describes the situation in the field of constructivist physics didactics, the problem, object and aim of the research, as well as the objectives, hypothesis, methodology and scientific novelty of the work.

Chapter 1, Theoretical and didactic aspects of constructivism in physics teaching, is theoretical and analytical in nature, being devoted to the conceptual grounding of the entire research. The chapter pursues four complementary directions: the evolution of educational paradigms in physics teaching, constructivism as the theoretical basis of modern didactics, the organisation of the physics lesson in a constructivist approach, and the physics laboratory as a constructivist learning environment. Starting from a historical analysis of how physics has been taught over time, the chapter arrives at outlining the operational tools of constructivism, the scale of educational paradigms and the 5E model, and at reconsidering the school laboratory as a central space for the construction of knowledge rather than an appendix to the lesson.

Subchapter 1.1. Educational paradigms in physics teaching begins by clarifying the concept of educational paradigm, starting from the definition given by Thomas Kuhn, for whom a paradigm represents a set of practices and standards specific to a period of science, paradigm shifts marking its progress [46]. This perspective is applied to the evolution of educational paradigms in physics teaching, previously analysed by Fensham [31] and Rudolph [58].

The historical evolution of educational paradigms is traced from the traditional education of Antiquity and the Renaissance, characterised by memorisation and the passive transmission of knowledge [50], through the Enlightenment and industrial education, to the progressive education of the early 20th century, associated with Dewey, Montessori, Piaget and Vygotsky, and, finally, to modern constructivist education. Each historical stage is associated with its own method of teaching physics, from empirical observation in Antiquity to creative experimentation and the use of the virtual laboratory in the contemporary period. The synthesis of this evolution is presented in Figure 1, which highlights the cumulative character of the paradigms: each stage retains the features of the previous one, adding new ones to them.

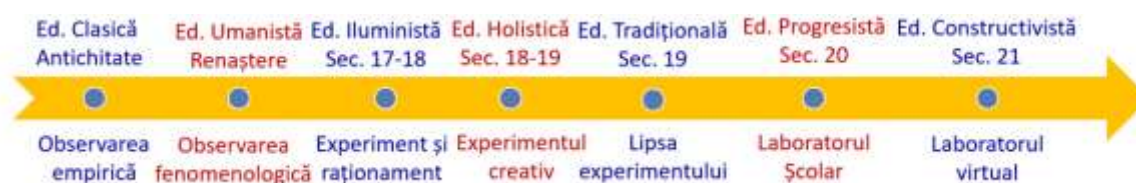


Fig. 1. The evolution of physics teaching within educational paradigms.

Within modern constructivist education, seven types of constructivism are identified, summarised in Table 1:

Table 1. Types of constructivism

Type of constructivism	Basic characteristics	Key representative
Cognitive constructivism	Learning as an active construction of knowledge, with emphasis on the stages of cognitive development	Jean Piaget
Social constructivism	Learning through social interaction and culture; the zone of proximal development	Lev Vygotsky
Radical constructivism	Knowledge as a subjective construction, with no absolute truth, only personal perspectives	Ernst von Glasersfeld
Pragmatic constructivism	Learning through experience and practical experimentation, with an active role in solving real problems	John Dewey
Cultural constructivism	Learning influenced by the cultural environment and language, with emphasis on symbols and meanings	Jerome Bruner
Technological constructivism	The use of technology to facilitate active and creative learning, through creation	Seymour Papert
Emotional constructivism	The role of emotions, motivation and emotional intelligence in the learning process	John D. Mayer

This typology provides the terminological framework on the basis of which the application of constructivism to physics didactics proper is analysed in the next subchapter.

Subchapter 1.2 examines constructivism as the theoretical foundation of modern didactics and the way its principles are concretely reflected in the organisation of the physics lesson. The evolution of educational paradigms presented in the previous subchapter is directly reflected in modern didactic practice, in which project-based learning, exploratory learning and discovery learning play an essential role in creating an active and collaborative learning environment [4]. The transition from teacher-centred teaching to teaching based on constant feedback underlines the importance of metacognition and of the theory of visible teaching and learning [41], students being encouraged to develop their capacity for self-regulation [43].

In the Moldovan pedagogical space, constructivism is analysed from several convergent perspectives: Botgros, Franțuzan and Bocancea [8] consider it one of the five fundamental formative components of scientific knowledge, alongside the systemic approach, interactivity, metacognition and authentic assessment, while Hadîrcă and Țîbuleac [38] place it among the most important modern educational paradigms. Celac [22] shows that it focuses on the student's internal resources, personal initiative and activism. In the same constructivist perspective, the Ukrainian researcher Davidenko A. A. [67], author of the reference monograph devoted to developing students' creative abilities in the process of learning physics, shows that the student cannot build authentic conceptual understanding by remaining a mere recipient of transmitted knowledge, but must be placed in the position of acting as a constructing subject, generating hypotheses, solutions and explanations himself, through his own cognitive effort.

Students' low motivation and lack of interest in the learning process [32] find a solution in the degree of autonomy offered to the student: the greater it is, the greater the chances of remarkable academic results [40], the upper limit of this independence being reached when students actively assume the teacher's educational objectives as their own learning objectives [12]. On this observation is built the central element of scientific novelty of the chapter, the scale of educational paradigms: Active learning has an effect size of about 0.35, comparable to that of frontal teaching delivered by a teacher with two years of experience; Learning through understanding reaches an effect of up to 0.80; and Learning through the assumption of objectives, the most advanced step, ranges between 0.80 and 1.30, with synergistic effects when several methods are integrated simultaneously [41; 42].

An essential role belongs to the student-teacher feedback loop, whose components are ranked by effect size on performance, from problem-based learning (0.26) and student-centred teaching (0.36), to formative assessment (0.48), peer tutoring (0.74), teacher-guided discussions (0.82), instant knowledge of students' perception of the lesson (1.29) and, the highest, the teacher's deep knowledge of his students' potential (1.62) — summarised in Figure 2.

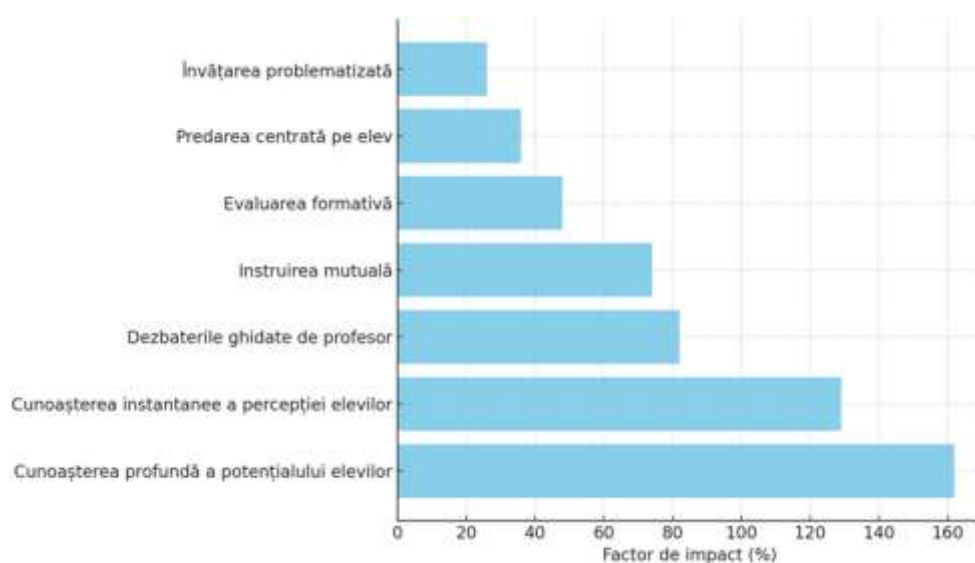


Fig. 2 Effect size of teaching and learning strategies according to the theory of visible learning and teaching.

Subchapter 1.3 analyses how conceptual understanding becomes the central objective of the organisation of the physics lesson, concretely materialised in the structure of the constructivist lesson following the 5E model. Physics teaching faces an international crisis, manifested by a decrease in the number of graduates choosing this subject for the baccalaureate and, subsequently, by low interest in related specialisations at university level [60]. The proposed solution lies in constructivism [14]: conceptual understanding becomes possible only

when the student makes a sustained cognitive effort, actively uses prior knowledge and develops metacognition, given that traditional frontal teaching, although widely proclaimed to be student-centred, often keeps the student in a passive role [36].

The concrete organisation of these principles is found in the structure of the constructivist lesson, modelled on the five phases of the 5E model, engagement, exploration, explanation, elaboration and evaluation [34], each of which is, by its nature, constructivist. The exploration phase is developed on the basis of the author's own research [20], which demonstrates how students' cognitive activation and authentic engagement can be supported through group collaboration, challenging questions and reflection on learning experiences. The characteristics of each phase are summarised in Table 3, which highlights the fact that feedback is constantly present in all five stages, together with the experiment and group discussions, as elements common to the entire model.

Table 3. Main characteristics of the phases of the 5E model

Engagement	Exploration	Explanation	Elaboration	Evaluation
Empathetic atmosphere	Group work	Different perspectives	Research project	Self-assessment
Encouraging curiosity	Open-ended questions	Analysis of available information	Independent research	Pair work
Challenging questions	Practical and independent activities	Multiple resources	Collaborative discussions	Portfolios
Activation of prior knowledge	Collective reflection	Facilitation of discovery	Personalised feedback	Formative assessment
Real-life situations	Sharing ideas	Group and class discussions	Guidance	Problem-solving ability
Concrete examples	Guided exploration	Conceptual understanding	One group – one project	Conceptual understanding
Positive and open feedback	Assessment of understanding	Different explanations	Real-life projects	Application of knowledge

The practical application of this model is illustrated using the example of the chapter “Mechanical work, power and mechanical energy” from the 7th-grade physics course, where the acquisition of conceptual understanding, procedural knowledge and scientific attitude is structured through open-ended questions, activation of prior knowledge, guidance of collective discussions and assessment of understanding.

Subchapter 1.4 examines the school physics laboratory from a constructivist perspective, analysing both the theoretical foundations of its organisation and the concrete conditions under which it can become an active learning environment. The physics laboratory is analysed from two complementary perspectives: as an environment whose equipment and organisation can support various constructivist didactic strategies, and through the correlation

between the learning environment and students' motivation for cognitive effort. Depending on the objectives pursued, laboratories are classified into three types: concept-based, oriented towards consolidating textbook knowledge; competence-based, functioning as research projects carried out by students; and mixed, which combine the two approaches, offering the most balanced framework for deep conceptual understanding [62]. Unlike traditional laboratories, rigidly structured by the "work procedure", those that offer more freedom allow students to construct their own knowledge through observation, reflection and analysis [45], increased autonomy contributing to greater interest, motivation and confidence of students in their own abilities [59].

This freedom of exploration is aligned with the four principles of radical constructivism: knowledge is constructed by the student, not transmitted by the teacher; its construction involves cognitive effort; pre-existing knowledge influences learning; and initial, superficial and local understanding gradually deepens [5]. An effective model for operationalising these principles is the studio-format school laboratory, in which the lesson and laboratory activity become a single entity, students achieving cognitive objectives higher than those in the traditional system [35].

The factors supporting the active character of learning in the laboratory are summarised in Table 4, structured on three interconnected levels: cognitive processes (speaking, listening, reading, writing, reflection), learning strategies (work in small groups, collaboration, analysis of problem situations) and didactic resources that stimulate interest in research [57].

Table 4. Factors of active learning

Cognitive processes	Learning strategies	Didactic resources
Speaking, listening, reading, writing, reflection	Work in small groups, collaboration, analysis of problem situations, discussions, laboratory journals	Traditional and digital materials that stimulate interest in research and understanding

The digitalisation of the laboratory has a significant impact on conceptual understanding, especially when real experiments are combined with simulations [3], the role of information technologies also being documented by Davidenko [68], who shows that digital tools increase learning effectiveness only when they are coherently integrated into the structure of the lesson. The level of students' conceptual understanding is directly proportional to the extent of use of the school laboratory [61].

The application of these principles is illustrated using the example of the laboratory work "Determining the average speed of a moving body", comparing the objectives of a constructivist approach, structured around research skills, cognitive objectives and big

scientific ideas, with those of a traditional approach, organised according to Bloom’s taxonomy, from knowledge to evaluation (see Table 5).

Table 5. Objectives of the laboratory work “Determining the average speed of a moving body”: constructivist vs. traditional approach

Constructivist approach	Traditional approach (Bloom’s taxonomy)
Research skills: observing the phenomenon, formulating the hypothesis, planning, collecting and analysing data, interpreting results	Knowledge: defining average speed, identifying the quantities involved
Cognitive objectives: understanding uniform rectilinear motion and average speed	Comprehension, Application: explaining the distance–time–speed relationship, applying the formula
Big scientific ideas: distance, uniform rectilinear motion, speed	Analysis, Synthesis, Evaluation: comparing results, formulating conclusions, arguing validity

This comparison highlights the advantage of the constructivist approach: it is not limited to verifying theoretical knowledge, but develops transferable research skills anchored in fundamental concepts of physics.

The theoretical research presented in this chapter is reflected in the papers Zelenschi [64], Calalb and Zelenschi [16] and Calalb and Zelenschi [20], which address, in the order of the subchapters, the evolution and comparative analysis of educational paradigms, the application of constructivism to the physics lesson, and models of constructivist physics learning environments.

Chapter 2, Methodological bases for applying constructivism in physics teaching, is methodological and applied in nature, extending the theoretical grounding of Chapter 1 towards concrete tools of didactic design. The chapter pursues three complementary directions: the constructivist foundations of physics learning, constructivist didactic models in physics teaching, and the application of constructivist strategies in teaching the chapter “Interactions” in the 7th grade. The foundations and models analysed are materialised through distinct didactic applications, of which the Flipped Classroom model is subjected to experimental validation in teaching the chapter “Rotational equilibrium”, while the IBSE model is illustrated through the design of a lesson on the topic “The force of gravity. Weight”.

Subchapter 2.1 establishes the epistemic and psycho-pedagogical foundations of constructivist physics learning and shows how the 5E model operationalises these foundations in the concrete structure of the lesson. The constructivist foundations of physics learning are understood not as a set of didactic methods but as a change of perspective on the nature of knowledge: learning is no longer a process of transmitting and accumulating information, but one of internal reconstruction of meaning, achieved through the student’s cognitive activity in

interaction with the educational environment. Three fundamental principles govern this process: conceptual reconstruction, through which the student becomes an active participant in his own learning, starting from his previous experiences and conceptions; active cognitive effort, which excludes passive learning and involves continuous reflection on new information; and cognitive resistance to change, whereby already formed cognitive structures are modified only through deep and meaningful learning, not through mere exposure to information.

The operationalisation of these principles is illustrated by the model proposed by Perkins [54], structured on five components: active participation of all students, use of prior knowledge, promotion of a climate of debate, motivation through stimulating questions, and revision of pre-existing conceptions. This model places the student at the centre of the educational process, transforming him into an active constructor of knowledge who collects data, formulates hypotheses, analyses results and applies his knowledge in new situations.

The multidimensional structure of knowledge, already introduced in Chapter 1, is applied here to a distinct topic: “Uniformly varied rectilinear motion. Acceleration”, 10th grade. Conceptual knowledge includes understanding the definition of uniformly varied motion and correctly interpreting the graphs of displacement, velocity and acceleration as functions of time; procedural knowledge concerns identifying the quantities in the problem statement, applying formulas and performing calculations; while axiological knowledge is formed through curiosity, positive feedback and the relevance of real-life examples.

The 5E model, developed by the BSCS group [10], is revisited here on an example different from the one in Chapter 1, illustrating its transferability to another topic: uniformly accelerated motion. The engagement phase starts from a virtual car race, with questions such as “What happens to the speed and position of the car while the accelerator is pressed?”; the exploration phase materialises in studying the free fall of a paper ball, students measuring the fall time and formulating their own observations; the explanation phase leads students, through guided discussions, to formulate the definition of uniformly accelerated motion themselves; the elaboration phase extends the concept through the analysis of motion graphs; and the evaluation phase requires the application of knowledge to complex real-life problems, such as calculating the acceleration of a car or the distance travelled by a stone thrown upwards.

Through this second applied example, subchapter 2.1 demonstrates that the 5E model is not a rigid structure but a flexible framework, transferable to different topics of the physics syllabus, retaining in all cases its intrinsically constructivist character.

Subchapter 2.2 introduces the Flipped Classroom model as a constructivist strategy for organising the lesson and experimentally validates its effectiveness on the topic “Rotational

equilibrium”. The Flipped Classroom model reorganises the traditional structure of the lesson, placing individual study of theoretical notions, through watching video lessons or analysing written materials, before class, so that class time can be used for applied activities, discussions and experiments [2]. The basic idea of the model, shown in Figure 3, is complemented by a direct comparison between the actions of the teacher and students in traditional teaching versus the Flipped Classroom, based on Bloom’s taxonomy and presented in Figure 4.



Figure 3. The Flipped Classroom model

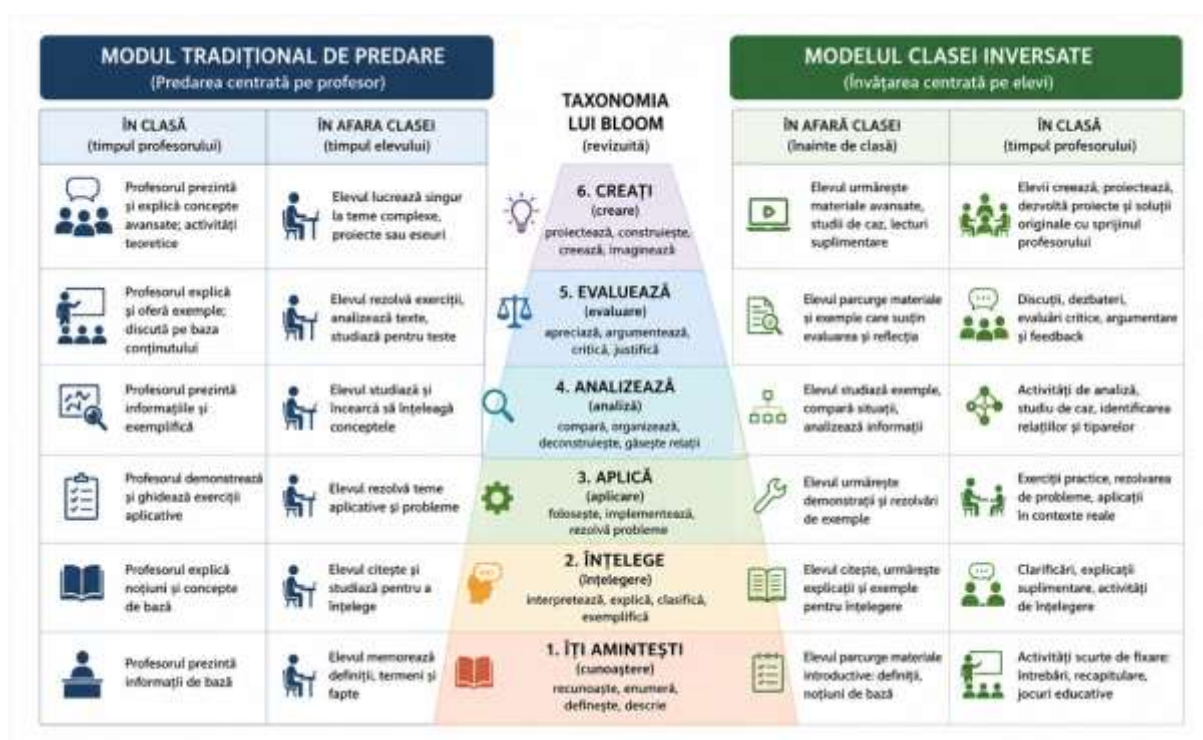


Figure 4. Comparison of the traditional teaching mode with the Flipped Classroom model, based on Bloom's taxonomy

Applying the model involves four principles: students' prior preparation for the lesson, intense interaction between students and teacher during class, personalised learning at each student's own pace, and the development of critical thinking through the practical application of concepts studied at home. The effectiveness of the model is confirmed internationally by a study conducted at the University of British Columbia, where students in the experimental group obtained significantly higher scores on conceptual assessment tests compared with the traditionally taught control group [29].

The experimental validation of the model was carried out during the 2022-2023 school year at the "Hyperion" Theoretical Lyceum in Chișinău, by comparing two 7th-grade classes: the experimental group (35 students), taught through the Flipped Classroom model, and the control group (36 students), taught through the traditional method, both covering the chapter "Rotational equilibrium". The results show an increase in academic quality of 96% in the

experimental class, compared with only 65% in the control class, the difference between the two methods being 48 percentage points in favour of the Flipped Classroom (see Table 6).

Table 6. Distribution of grades in the experimental class and in the control class

	Control class (pre-test → post-test)	Experimental class (pre-test → post-test)
Average grade	7.00 → 7.35	7.24 → 7.69
Quality, %	25.0 → 41.18	33.3 → 59.38

The qualitative leap is also visible in Figure 5, which shows the shift of the grade distribution from the predominance of grades 6 and 7 in the pre-test towards the predominance of grades 8, 9 and 10 in the post-test in the experimental class.

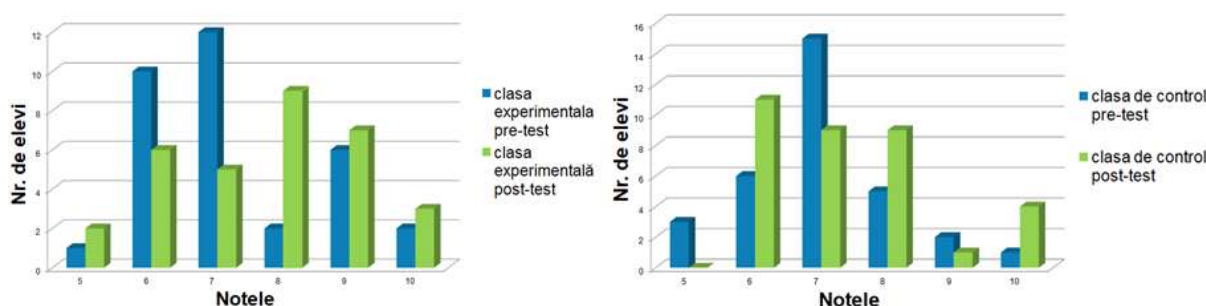


Figure 5. Comparative analysis of pre-test and post-test grades in the experimental and control classes

Subchapter 2.3 compares three constructivist strategies applied to teaching the chapter “Interactions” and illustrates, through a detailed example, the design of a complete lesson in the IBSE model. For the 16 hours allocated to the chapter “Interactions” in the 7th grade, organised in four didactic projects (Force as a vector, The force of gravity, The elastic force, The friction force), three constructivist approaches are compared: project-based learning, inquiry-based learning (IBSE) and the theory of visible learning and teaching (VLT). The three strategies differ in the degree of freedom granted to the student and in the nature of the student–teacher feedback loop: the classic didactic project follows a general logical matrix (objectives, resources, activities, results, impact), whereas the IBSE project additionally imposes an explicit investigative structure, starting from an initial question and advancing through hypothesis, experiment and generalisation (Table 7).

**Table 7. Comparative logical matrix of the didactic project “The force of gravity”:
classic project-based approach vs. IBSE approach**

	Classic didactic project	IBSE project
Central activity	Forming one’s own ideas, supporting research within the laboratory work	Initial question, formulating and testing the hypothesis, developing the model
Role of the student	Individual and group research, collective debate	Putting forward the hypothesis, guided experiment, analysis of own data

Impact	Formation of key competences	Formation of analytical competences, scientific vocabulary and communication
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According to the theory of visible teaching and learning, the most powerful didactic strategy depends not on the external form of the method but on the quality of the student–teacher feedback loop: teaching based on constant feedback reaches an effect size of 1.2, compared with only 0.4 for conventional teaching, which triples students’ academic success [41]. The IBSE strategy fits this direction, since each stage of the investigative cycle, from formulating the hypothesis to debating the results, involves a constant exchange of questions and answers between student and teacher.

The concrete application of these principles is illustrated by a lesson structured on the cyclical model Evocation – Formulating hypotheses – Testing hypotheses – Discussing results – Reflection [13], an organisation consonant with the methodological direction promoted by Davidenko and Bocancea [28] for STEM/STEAM projects in physics. The lesson starts from the problem question “What would happen if there were no force of gravity?”, students formulating their own hypotheses which they test experimentally, measuring the force of gravity of different masses with a dynamometer and plotting the relationship obtained. From these data, students discover on their own the direct proportionality relationship $G = mg$, as well as the distinction between the force of gravity and weight, without the teacher giving the answer directly.

The complementary roles of the teacher, as facilitator of discovery, and of the students, as active researchers, throughout the five stages of the lesson are summarised in Table 8.

Table 8. Actions of the teacher and students in the constructivist IBSE lesson

Lesson stage	Teacher’s actions	Students’ actions
Evocation	Formulates the problem question, facilitates the discussion, without defining the concepts	Formulate their own conceptions of the force of gravity
Formulating hypotheses	Records the hypotheses, guides the clarification of terms	Formulate and argue a working hypothesis
The experiment	Observes actively, guides through questions, without validating directly	Measure, collect data, plot the G–m relationship
Discussing the results	Facilitates dialogue and generalisation	Present the results, compare, formulate conclusions
Reflection	Formulates metacognitive questions, provides feedback	Self-assess, reflect on difficulties

Through this approach, teaching the topic The force of gravity transforms the physics lesson from a transmission of knowledge into an experience of personal discovery, the student becoming a researcher of his own ideas.

The theoretical research presented in chapter two is developed at length in Calalb and Zelenschi [17], *Constructivism in physics teaching*, Zelenschi and Calalb [66], *Applying the*

flipped classroom method in teaching the chapter Rotational equilibrium in the 7th-grade physics course, Calalb and Zelenschi [19], Constructivist methods of teaching interactions in the 7th grade. Comparative analysis.

Chapter 3, Analysis and validation of constructivist approaches in physics learning, is analytical and empirical in nature, capitalising on the conceptual and methodological tools developed in the previous chapters. The chapter pursues three complementary directions: the analysis of the national curricular framework from the perspective of the constructivist dimensions of learning, the construction of scientific knowledge in modern physics, and the empirical analysis of academic results obtained in the context of applying constructivist approaches. Starting from an examination of how curricular documents transpose constructivist principles from the conceptual level to didactic practice, the chapter advances towards modern physics content with particular constructivist potential, such as astrophysics, to arrive, finally, at the statistical analysis of the results of complementary empirical investigations carried out at different school levels.

Subchapter 3.1 analyses how four constructivist dimensions, the status of the student, the construction of knowledge, interaction and argumentation, and the role of the teacher, are reflected in the three documents that regulate physics teaching in the Republic of Moldova: the Concept, the Curriculum and the Implementation Guide of the subject “Physics. Astronomy”. The analysis starts from the observation that these three documents operate at different levels of curricular organisation, one formulating meaning and direction, another structuring content and competences, and the third proposing concrete ways of working, a distinction that can be understood in terms of the model separating the conceptual, structural and processual dimensions of the curriculum [37]. The research examines whether and how constructivist principles, present at the declarative level, become operational in real didactic practice.

The analysis of the four dimensions shows a constant pattern: the status of the student as an active subject of learning and the construction of knowledge through experience, investigation and modelling remain relatively coherent across the three documents, being present in the Concept at the conceptual level, in the Curriculum as a structure derived from competences, and in the Guide as concrete actions. By contrast, interaction, argumentation and the role of the teacher are significantly reduced at the level of the Curriculum, where they appear mostly implicitly, being partially recovered in the Guide through strategies and forms of organisation, without becoming stable in real practice. This uneven distribution of the four dimensions across the three levels of explicitness is summarised comparatively in Table 9.

Table 9. Reflection of constructivist dimensions in curricular documents

Constructivist dimension	Concept (conceptual level)	Curriculum (structural level)	Guide (operational level)
Status of the student and nature of learning	Active student; learning as construction and use of knowledge	Student as agent of problem solving, status derived from competences	Student active in action, collaboration, self-regulation
Construction of knowledge	Observation, experiment, hypothesis, modelling	Exploration, interpretation, application; integrated investigation	Investigations, experiments, models, including digital ones
Interaction, argumentation, communication	Argumentation and communication as validation of knowledge	Communication integrated into competences, implicit interaction	Debate, collaboration, presentation, explicit argumentation
Role of the teacher	Facilitator, mentor, designer of contexts	Organiser of situations and progression, role derived from structure	Guidance, organisation, adaptation, role defined through actions

The differences do not concern the content of the constructivist ideas, present in all three documents, but their degree of explicitness and the level at which they become effectively applicable in educational practice. The curricular framework thus functions as a system of interdependent documents, in which coherence results not from a common explicit model but from partial correspondences between the levels of design and implementation [6].

Subchapter 3.2 examines the constructivist potential of modern physics content, such as black holes and gravitational waves, and proposes a framework for organising the lesson through which this content, inaccessible to direct observation, can nevertheless be conceptually constructed by the student. Phenomena such as black holes and gravitational waves cannot be observed directly and cannot be reproduced experimentally in the classroom, which gives them a particular epistemic specificity: their understanding is built by following the evolutionary stages, by interpreting physical relationships and by explaining the effects produced, not through direct perception. The formation of a black hole is traced through the stages of stellar evolution, from the main sequence, through the red giant phase, to the supernova explosion, gravitational collapse producing a black hole only if the mass of the remaining core exceeds 2.5-3 solar masses (the Tolman-Oppenheimer-Volkoff limit); below this threshold, the star becomes a neutron star or a white dwarf. The two fundamental properties of a black hole, the Schwarzschild radius and density, are exemplified numerically for a concrete case (a black hole

of three solar masses), while the examples of Sagittarius A*, at the centre of the Milky Way, and the closest known black hole, in the HR 6819 system, are illustrated in Figure 6.



Figure 6. The closest black hole, marked with a red circle

Gravitational waves, predicted by Einstein in 1916, are described by relationships linking their amplitude and frequency to the masses of the bodies involved, their first direct detection, in 2015, being recognised by the Nobel Prize in 2017 [1]. The operating principle of the LIGO interferometer, capable of detecting variations in the length of its arms of the order of 10^{-18} m, much smaller than the diameter of a proton, is illustrated in Figure 7, together with the international network of similar observatories (GEO600, LIGO India, VIRGO, KAGRA), which increase global detection capacity.

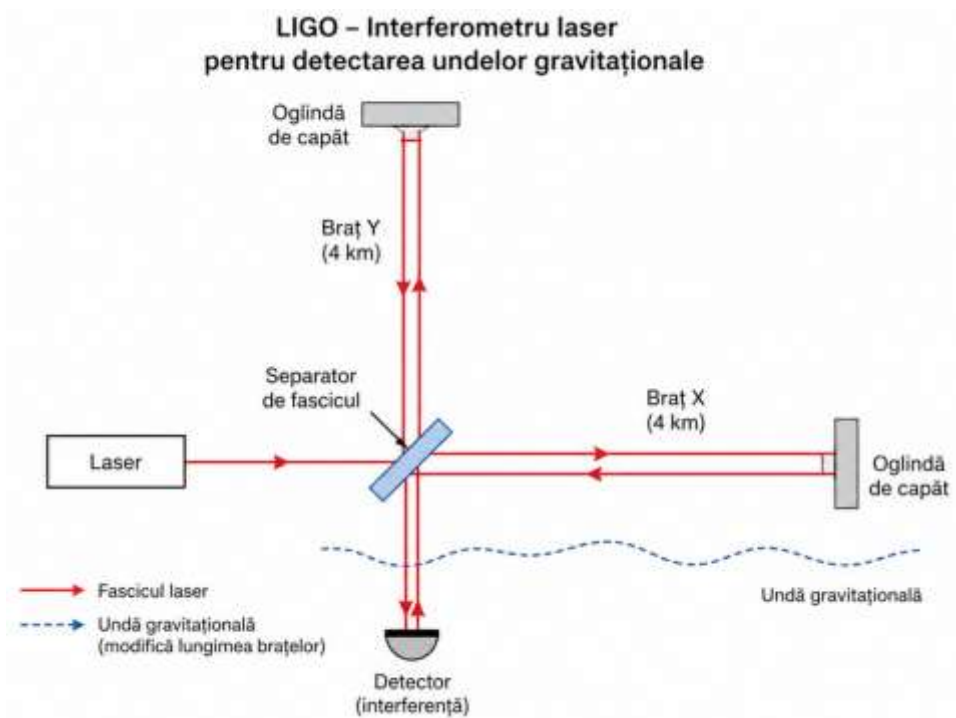


Figure 7. LIGO operating principle

Since the student cannot directly verify these phenomena, the organisation of learning becomes essential: the process can be described as a gradual transition from the student's direct involvement in activity, through concrete tasks, towards autonomy, temporarily supported by the scaffolding offered by the teacher through questions, partial explanations and successive corrections, support that is reduced as understanding consolidates (see Figure 8).

Figure 8. The constructivist structure of learning and the role of scaffolding in the



This organisation is materialised through a set of principles for organising the lesson based on teacher-guided inquiry, summarised in Figure 9, which shows how involving students in formulating questions, developing hypotheses and constructing explanations represents not only a didactic strategy but the functional expression of constructivism in learning activity.

Figure 9. Basic principles of organising teacher-guided inquiry-based learning



Thus, modern physics becomes, by its very epistemic nature, fertile ground for the constructivist approach: the student does not receive ready-formulated concepts, but

reconstructs them step by step, guided by the teacher, exactly as in the case of the classical content of the syllabus.

Subchapter 3.3 empirically analyses the academic results obtained in the context of applying constructivist approaches and separately examines the relationship between performance in laboratory work and the results of summative assessment in the study of Electrokinetics. The first investigation was carried out during the 2023–2024 school year at the “Hyperion” Theoretical Lyceum in Chişinău, on a sample of 195 students from the 6th grade (93 students), 8th grade (72 students) and 10th grade (30 students), under the application of an integrated teaching programme based on the 5E model, the Flipped Classroom and the Early Physics Approach.

Table 10. Objectives, questions and hypotheses of the research

Objective	Research hypothesis
Analysis of academic performance in the context of the integrated application of constructivist strategies at different school levels	The integrated application of constructivist strategies is associated with favourable academic results at the school levels analysed.
Determining the laboratory–assessment correlation	There is a significant positive correlation between laboratory grades and summative assessment grades
Highlighting gender differences	There are performance differences between boys and girls, which diminish with age

The results confirm all three hypotheses. Comparison of the cohorts at the investigated levels indicates higher values of academic performance in the 8th and 10th grades than in the 6th grade, the average grade in laboratory work rising from 7.11 to 8.27, and academic quality (the percentage of grades above 8) from 17.2% to 43.06% in the 8th grade. The Pearson correlation between laboratory grades and summative assessment grades is positive and statistically significant in all three grades, reaching its maximum value in the 8th grade ($r = 0.836$; $p < 0.001$), where linear regression analysis shows that 69.8% of the variability of assessment grades is explained by laboratory performance (Table 11, Figure 11).

Table 11. Pearson correlations between laboratory work and summative assessments

Grade	Pearson r	R^2 (explained variability)
6th	0.747	55.8%
8th	0.836	69.8%
10th	0.656	43.1%

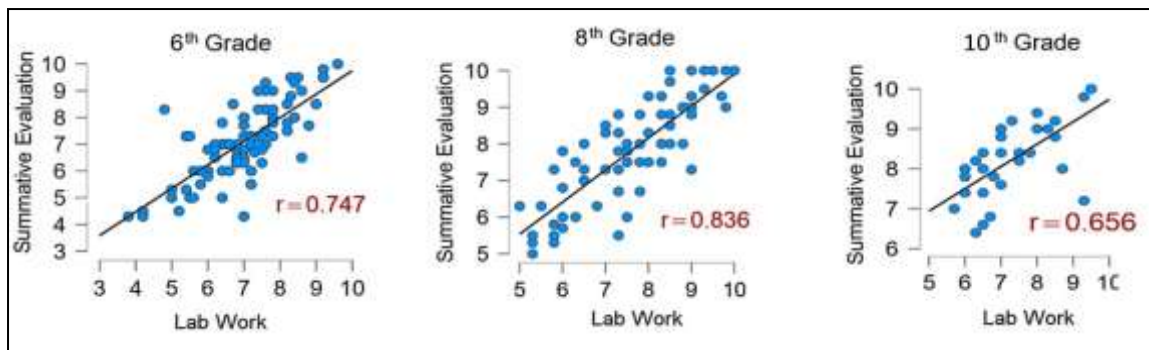
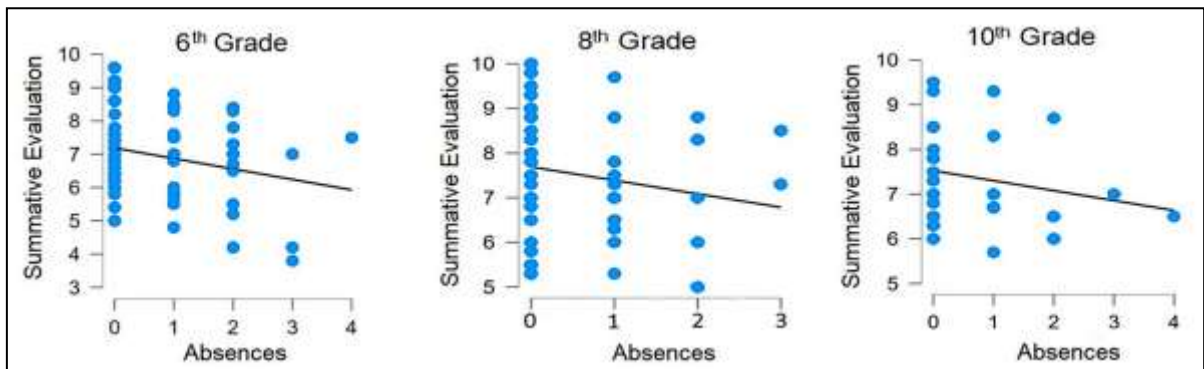


Figure 11. Scatter plot for the correlation between summative assessment results and laboratory work grades

Additional analysis of the relationship between absences and academic success (Figure 12) shows a slight decrease in results as the number of absences increases, indirectly confirming the role of constant attendance at laboratory classes in consolidating conceptual



understanding.

Figure 12. Scatter plot for the correlation between summative assessment grades and absences

Gender differences in performance were tested using Student's t-test, applied separately to laboratory grades and summative assessment grades in each of the three grades (Table 12).

Table 12. Student's t-test for gender differences

Grade	Indicator	t	df	p
6th	Summative assessment	2.877	91	0.005
	Laboratory work	1.789	91	0.077
8th	Summative assessment	1.478	70	0.144
	Laboratory work	2.529	70	0.014
10th	Summative assessment	-0.223	28	0.825
	Laboratory work	0.185	28	0.854

The data show a statistically significant difference ($p < 0.05$) in summative assessment in the 6th grade and in laboratory work in the 8th grade, in both cases in favour of girls, whereas for the other four situations the difference does not reach the threshold of statistical significance. In the 10th grade, neither of the two differences is significant, and the negative value of the t

coefficient for summative assessment indicates a non-significant advantage for boys. The results support, albeit partially and not uniformly across all indicators, the tendency for gender differences to diminish with the transition from lower secondary school to high school.

A second empirical investigation, conducted on a sample of 98 8th-grade students (58 girls, 40 boys), analysed the specific impact of the laboratory work “Determining the power of an electric bulb” on summative assessment in the chapter “Electrical phenomena”. The quality of the conclusion formulated by the student in the laboratory report, scored on a scale from 0 to 3 points, proved to be a strong statistical predictor of the summative assessment grade, explaining approximately 35.7% of the variability of the results (**Figure 13**).

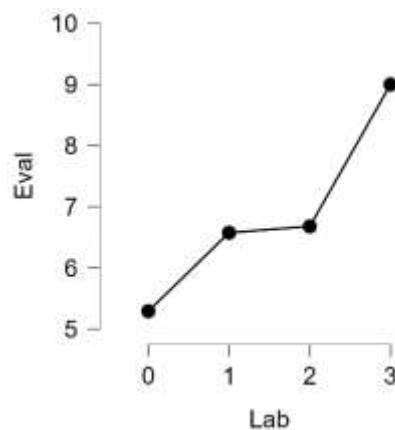


Figure 13. Correlation between assessment grades and laboratory scores

The gender-differentiated analysis, also carried out for this distinct sample, is illustrated separately for the assessment results (Figure 14) and for those of the laboratory work (Figure 15), confirming a pattern compatible with that observed in the previous investigation: the performance of girls and boys remains comparable, without substantial differences at this age level.

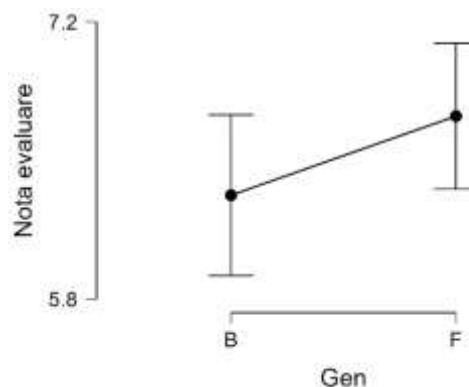


Figure 14. Gender correlation for grades obtained in the assessment

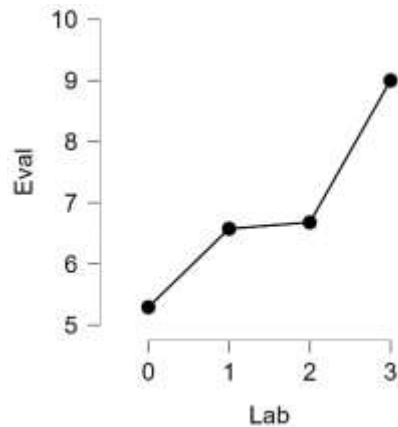


Figure 15. Gender correlation for grades obtained in the laboratory work

The result confirms, on a distinct chapter of the syllabus, the same relationship observed at the level of the entire sample: laboratory activity explains 35.7% of the variability of summative assessment grades, reinforcing the conclusion that laboratory performance is a consistent predictor of the student's academic success, consolidating, in a distinct thematic context, the relationship between laboratory performance and summative assessment results.

The results presented in this chapter are reflected in the papers Zelenschi [65], *Constructivist premises in the new concept of the subject Physics and Astronomy*, Calalb, Dabija and Zelenschi [15], *Integrating Black Holes and Gravitational Waves into School Physics*, Calalb and Zelenschi [21], *The Effects of Constructivist Physics Lessons and Laboratories on Students' Academic Success*, and Calalb and Zelenschi [18], *The impact of laboratory work on summative assessment results in the study of Electrokinetics in the 8th grade*.

GENERAL CONCLUSIONS AND RECOMMENDATIONS

GENERAL CONCLUSIONS AND RECOMMENDATIONS

General conclusions

1. The theoretical and didactic approach developed in the chapter “Theoretical and didactic aspects of constructivism in physics teaching” highlighted, at the level of the fundamental mechanisms of learning, that conceptual understanding does not result from “the passive transmission of knowledge”, but is constituted exclusively under conditions of the student’s involvement in processes of “thinking, comparing, explaining and confronting one’s own ideas”, which confirms the active and constructive character of knowledge and its dependence on experience, interaction and reflection.
2. The research on the evolution of educational paradigms, carried out within the same theoretical and didactic framework, revealed that the development of physics teaching follows a cumulative logic in which “each stage contains the characteristics of the previous stages”, a structural relationship being configured between paradigms and forms of teaching, from “empirical observation” and “phenomenological observation” to the “school laboratory” and constructivist strategies based on active learning, collaboration and investigation.
3. The didactic modelling carried out in the chapter led to the construction of a scale of educational paradigms, differentiated by effect size on learning, which highlights the transition from learning by doing, with an effect of approximately 0.35, to learning through understanding, with an effect of about 0.80, and up to learning through the assumption of cognitive objectives, with values between 0.80 and 1.30, the differences being explained by the level of cognitive engagement and the complexity of didactic communication.
4. The analysis of the role of feedback, carried out within the paradigm of visible teaching and learning, demonstrated the existence of a proportional relationship between the level of feedback and students’ academic success, this relationship being supported by the effect values associated with didactic strategies: formative assessment – 0.48, guided discussions – 0.82 and knowing how students understood the teacher’s message – 1.29, which confirms that effective learning depends on the existence of permanent two-way communication.
5. The investigation of the cognitive processes involved in physics learning led to the identification of a functional core of conceptual understanding, defined by the interdependence between “the student’s cognitive effort”, “pre-existing knowledge” and “metacognition”, the latter playing a decisive role in the self-regulation and deepening of learning, which confirms

that understanding is constituted as an internal process, built progressively on the basis of existing cognitive structures.

6. The exploration of the theoretical and didactic framework for applying constructivism showed that it becomes operational only through the coherent integration of the fundamental structures of learning, namely the 5E model, laboratory activity organised as a research process and the principles of the “Nature of Science”, under conditions in which “feedback is present in every phase of the lesson” and students go through authentic processes of investigation, from formulating hypotheses to constructing explanatory models, which transforms the physics lesson into a space for the progressive construction of knowledge.

7. The chapter “Methodological bases for applying constructivism in physics teaching” configures the didactic design of physics learning as an intentional organisation of the student’s activity around conceptual reconstruction, active cognitive effort and the resistance of cognitive structures to change, these principles being transposed methodologically through the use of prior knowledge and the use of stimulating didactic questions.

8. The research on the methodological framework of constructivist teaching highlighted the use of the multidimensional character of knowledge, through the integration of the conceptual, procedural and axiological dimensions into lesson design, this integration being achieved by correlating objectives, activities and results in logical-matrix structures and by orienting the didactic approach towards the practical application of knowledge in varied contexts.

9. At the level of the organisation of learning, metacognition takes shape as an explicit methodological tool, integrated into the structure of the lesson through monitoring, reflection and self-assessment activities, which allow the continuous regulation of the learning process and the adaptation of students’ strategies to the proposed tasks.

10. The analysis of the organisation of didactic activities led to highlighting collaboration as a form of structuring didactic action, the lesson being built on group work, debate and interaction, in which students formulate hypotheses, discuss results and collectively construct knowledge, while the teacher organises and guides this process.

11. The examination of didactic models and strategies showed that constructivist teaching is achieved through a coherent set of methodological structures, in which the 5E model progressively organises learning activities through the phases of engagement, exploration, explanation, elaboration and evaluation, while strategies such as inquiry-based learning, project-based learning, problem-based learning, exploration, reflection and the use of simulations represent distinct forms of organising students’ cognitive action.

12. The analysis of the organisation of the physics lesson in constructivist models highlighted different ways of structuring the didactic approach, in which the Flipped Classroom model reorganises the distribution of activities between individual study and class activity, and the data presented in the application indicate values such as 96% for the level of achievement in the experimental class compared with 65% in the control class, an increase in the average grade of 6% compared with 5% and an effect 48% greater, while the cyclical IBSE model structures the lesson by correlating the stages of evocation, formulation of hypotheses, testing, interpretation and reflection with the actions of the teacher and students, the differences between the models being determined by the level of student autonomy, the degree of structuring of activities and the role of feedback.

13. The chapter “Analysis and validation of constructivist approaches in physics learning” highlights that the distribution and functioning of constructivism within the curricular framework is achieved not as an explicit didactic model, but as a differentiated system across the conceptual, structural and operational levels, in which the constructivist dimensions are coherently present but unevenly formulated and distributed among the Concept, the Curriculum and the Guide, so that their effective functioning becomes dependent on didactic transposition, while dimensions such as the status of the student, interaction, argumentation and the role of the teacher suffer differentiated losses in the implementation process, which explains the partial and unstable character of the application of constructivism in practice.

14. The research showed that the epistemic specificity of modern physics content and its consequences for learning determine a profound reconfiguration of the way understanding is constructed, given that the phenomena analysed are not accessible to direct observation and cannot be verified experimentally in the usual way. In this context, learning takes place through modelling, the interpretation of physical relationships and the correlation of quantities, while fundamental concepts are integrated into complex explanations, which extends experimental activity towards data analysis and the interpretation of models and transforms constructivism from a didactic option into an epistemic condition of understanding.

15. The concrete functioning of constructivist learning in the physics lesson is ensured through mechanisms such as scaffolding, guidance through questions and feedback, and the organisation of a progression from guided to independent activity, in which interaction, autonomy and student involvement are built through the deliberate structuring of activity, which shows that the effectiveness of learning depends on how these mechanisms are integrated and supported in the lesson.

16. The empirical validation of the relationship between the organisation of learning and academic performance is reflected in a systematic evolution of students' results, in which the laboratory average increases from 7.11 in the 6th grade to 8.27 in the 10th grade, and the assessment average from 7.00 to 7.38, concurrently with the increase in the percentage of grades above 8 from 17.2% to 43.06%. These trends are supported by high correlations between laboratory performance and academic results, with Pearson coefficient values of $r = 0.747$, $r = 0.836$ and $r = 0.656$, as well as by regression models explaining between 43.1% and 69.8% of the variation in performance, highlighting the consistency of the relationship between performance in laboratory activities, carried out in the context of the constructivist organisation of learning, and academic results at the school levels analysed.

17. Within this framework, the results obtained highlight differentiated manifestations of academic performance in the context of the constructivist organisation of learning. In the study focused on Electrokinetics, performance in laboratory work explains 35.7% of the variation in summative assessment results, and students who did not correctly formulate the conclusion of the work obtained an average of approximately 5.29 in the assessment, compared with approximately 9.00 for students who formulated it completely. In the cohorts analysed, the gender differences identified in lower secondary school are not statistically significant at the high school level, and students with high initial performance show greater progress, of 23.5%, compared with 12.6% for the other students. These results, obtained in distinct empirical investigations, highlight the consistency of the relationship between student activity, the constructivist organisation of learning and academic performance in different curricular contexts and at different school levels.

Recommendations

At the level of the Ministry of Education and Research

1. It is recommended to revise the physics curricular documents by explicitly correlating the requirements concerning student activity, the organisation of learning and assessment, so that they are formulated coherently across the Concept, the Curriculum and the Guide.
2. It is recommended to develop a unified national methodological framework for physics teaching, establishing common guidelines on didactic design, the use of formative assessment and the role of feedback in the teaching–learning–assessment process.
3. It is recommended to establish a system for monitoring curriculum implementation, based on the analysis of students' results, which allows curricular decisions to be correlated with real data from practice and official documents to be adjusted periodically.

At the level of research institutions

4. It is recommended to carry out empirical studies that establish, on the basis of data, the relationship between the way didactic activity is organised and students' results in physics, using measurable and comparable indicators.
5. It is recommended to develop and validate standardised instruments that allow the assessment of students' progress beyond summative results, with a view to using them in research and in the systemic analysis of educational data.

At the level of higher education institutions – initial training

6. It is recommended to explicitly include the constructivist approach in the initial training of physics teachers, through didactic design activities oriented towards organising learning around student activity and integrating investigation into the lesson.
7. It is recommended to organise teaching practice so that students design and deliver lessons based on constructivist principles, followed by an analysis of how pupils were engaged and of the results obtained.

At the level of higher education institutions – continuing training

8. It is recommended to organise continuing training programmes for physics teachers focused on analysing and improving existing lessons, by applying the constructivist approach and correlating the way learning is organised with students' results.

At the level of educational institutions (schools)

9. It is recommended to organise the physics teaching process so that lessons are consistently structured around student activity, through the use of tasks that require explaining, comparing and confronting ideas, as well as through the integration of investigative activities into the lesson.
10. It is recommended to establish internal practices for analysing students' results in physics, which allow the way learning is organised to be correlated with the performance obtained and didactic activities to be adjusted at class level.

At the level of methodological committees

11. It is recommended to use a common framework for analysing physics lessons, based on constructivist orientation criteria, in order to assess how students are engaged and how learning activities are organised.

At the level of the teacher

12. It is recommended to design and deliver physics lessons based on constructivist principles, by organising student activity in tasks that require explaining, comparing and confronting ideas.

13. It is recommended to make systematic use of two-way feedback throughout the lesson, in order to regulate learning and correlate students' ways of working with the results obtained.

BIBLIOGRAPHY

1. ABBOTT, B. P. et al. Observation of gravitational waves from a binary black hole merger. In: *Physical Review Letters*. 2016, 116(6), Article 061102. Available: <https://doi.org/10.1103/PhysRevLett.116.061102>
2. AKÇAYIR, G., AKÇAYIR, M. The flipped classroom: A review of its advantages and challenges. In: *Computers & Education*. 2018, 126, 334-345. Available: <https://doi.org/10.1016/j.compedu.2018.07.021>
3. BANDA, H. J., NZABAHIMANA, J. Effect of practical work in physics on students' academic achievement, conceptual understanding and science process skills: A systematic review. In: *African Journal of Research in Mathematics, Science and Technology Education*. 2021, 25(3), 398-411. Available: <https://doi.org/10.1080/18117295.2021.1933408>
4. BARRON, B., SCHWARTZ, D. L., VYE, N. J., MOORE, A., PETROSINO, A., ZECH, L., BRANSFORD, J. D. Doing with understanding: Lessons from research on problem- and project-based learning. In: *The Journal of the Learning Sciences*. 1998, 7(3-4), 271-311. Available: <https://doi.org/10.1080/10508406.1998.9672056>
5. BEATTY, I. D., GERACE, W. J. Technology-enhanced formative assessment: A research-based pedagogy for teaching science with classroom response technology. In: *Journal of Science Education and Technology*. 2009, 18(2), 146-162. Available: <https://doi.org/10.1007/s10956-008-9140-4>
6. BÎRNAZ, N. Monitorizarea curriculumului prin prisma documentelor de politici curriculare în viziunea profesorilor de biologie. In: *Studia Universitatis Moldaviae (Seria Științe ale educației)*. 2025, 5(185). Available: [https://doi.org/10.59295/sum5\(185\)2025_09](https://doi.org/10.59295/sum5(185)2025_09)
7. BOCANCEA, V. Aspects of implementing STEM/STEAM projects in the study of physics in general education. In: *Perspective interdisciplinare asupra predării și învățării științelor*. CEP UPSC, 2025, pp. 93-98. Available: <https://doi.org/10.46727/c.11-04-2025>
8. BOTGROS, I., FRANȚUZAN, L., BOCANCEA, V. Componentele paradigmei formării competenței de cunoaștere științifică în învățământul preuniversitar. In: *Acta et Commentationes (Științe ale Educației)*. 2013, 1(2), 40-48.
9. BOTGROS, I., GORDIENCO, A., ȘARGAROVSKI, S. Proiectarea constructivistă - siguranță în eficientizarea procesului educațional la fizică. In: *Materialele Conferinței Republicane a Cadrelor Didactice: Științe exacte (Vol. 1)*. Universitatea de Stat din Tiraspol, 2018, pp. 141-146. Available: https://ibn.idsi.md/ro/vizualizare_articol/95132
10. BYBEE, R. W., TAYLOR, J. A., GARDNER, A., VAN SCOTTER, P., CARLSON, J., WESTBROOK, A., LANDES, N. The BSCS 5E instructional model: Origins and effectiveness. BSCS, 2006. Available: https://bscs.org/wp-content/uploads/2022/01/bscs_5e_full_report-1.pdf
11. CALALB, M. Evaluation of the Moldovan concept of physics and astronomy as a school subject in light of modern science education. In: *Culegerea de lucrări a*

conferinței științifice internaționale Perspective interdisciplinare asupra cunoașterii, Chișinău, 8 mai 2026. CEP UPSC, 2026, pp. 82-100.

12. CALALB, M. Learning by being or assumption of cognitive goals. In: *Studia Universitatis Moldaviae. Seria Științe ale Educației*. 2020, 5(135), 49-54. Available: <https://doi.org/10.5281/zenodo.3967033>
13. CALALB, M. Pedagogia învățării prin investigație și impactul ei asupra deprinderilor de cercetare științifică și învățare pe tot parcursul vieții. In: *Studia Universitatis Moldaviae, Seria Științe ale Educației*. 2017, 5(105), 32-39. Available: https://ojs.studiamsu.md/index.php/stiinte_educatiei/article/view/2252
14. CALALB, M. The constructivist principle of learning by being in physics teaching. In: *Athens Journal of Education*. 2023, 10(1), 139-152. Available: <https://doi.org/10.30958/aje.10-1-8>
15. CALALB, M., DABIJA, V., **ZELENSCHI, I.** Integrating Black Holes and Gravitational Waves into School Physics. In: *Învățare activă pentru dezvoltare durabilă*, 15 noiembrie 2024, Chișinău. Chișinău, Republica Moldova: CEP UPS „I.Creangă”, 2024, pp. 34-44. ISBN 978-9975-46-989-0. <https://doi.org/10.46727/c.15-11-2024.p34-44>
16. CALALB, M., **ZELENSCHI, I.** Abordări constructiviste la lecția de fizică. In: *Materialele Conferinței Republicane a Cadrelor Didactice: Didactica științelor exacte*, 26-27 februarie 2022, Chișinău. Chișinău: Tipografia Universității de Stat din Tiraspol, 2022, Vol. 1, pp. 264-268. ISBN 978-9975-76-382-0 https://ibn.idsi.md/sites/default/files/imag_file/p-264-268_1.pdf
17. CALALB, M., **ZELENSCHI, I.** Constructivismul în predarea fizicii. In: *Acta et Commentationes, Sciences of Education*, 2023, nr. 3(33), pp. 76-85. ISSN 1857-0623, E-ISSN 2587-3636. <https://doi.org/10.36120/2587-3636.v33i3.76-85>
18. CALALB, M., **ZELENSCHI, I.** Impactul lucrărilor de laborator asupra rezultatelor evaluării sumative la studierea electrocineticii în clasa a VIII-a. In: *Perspective interdisciplinare asupra predării și învățării științelor*, 25 aprilie 2024, Chișinău. Chișinău: CEP UPS „I. Creangă”, 2024, pp. 233-244. ISBN 978-9975-46-933-3. <https://doi.org/10.46727/c.25-04-2024.p233-244>
19. CALALB, M., **ZELENSCHI, I.** Metode constructiviste de predare a interacțiunilor în clasa VII. Analiză comparativă. In: *Abordări inter/transdisciplinare în predarea științelor reale, (concept STEAM).*, Ed. Ediția a 2-a, 28-29 octombrie 2022, Chișinău. Tipografia UST, 2022, Ediția a 2-a, pp. 388-393. ISBN 978-9975-76-411-7. https://ibn.idsi.md/sites/default/files/imag_file/388-393_3.pdf
20. CALALB, M., **ZELENSCHI, I.** Modele de medii constructiviste de învățare a fizicii. In: *Science and education: new approaches and perspectives*, Ed. 25, 24-25 martie 2023, Chișinău. Chișinău: CEP UPSC, 2023, Seria 25, Vol.3, pp. 346-352. ISBN 978-9975-46-787-2. <https://doi.org/10.46727/c.v3.24-25-03-2023.p346-352>
21. CALALB, M., **ZELENSCHI, I.** The Effects of Constructivist Physics Lessons and Laboratories on Students' Academic Success. In: *Acta Didactica Napocensia*, 2024, nr. 17(2), pp. 99-111, nr.<https://doi.org/10.24193/adn.17.2.8>

22. CELAC, V. Valorizarea instrumentelor de învățare cognitiv-constructivistă în procesul de formare a competențelor elevilor. In: *Tradiție și inovație în educație: Învățământul general: Tradiție și inovație* (Vol. 1). Universitatea de Stat din Tiraspol, 2019, pp. 192-201.
23. CESCHI, A., PERINI, M., SCALCO, A., PENTASSUGLIA, M., RIGHETTI, E., CAPUTO, B. Foster employability and fight social exclusion through the development of lifelong learning key competences: Reviewing twenty years of lifelong learning policies. In: *European Journal of Training and Development*. 2021, 45(6/7), 475-511. Available: <https://doi.org/10.1108/EJTD-07-2019-0126>
24. CIASCAI, L., coord. Model ciclic de predare-învățare bazat pe investigație. Cluj-Napoca: Presa Universitară Clujeană, 2016. Available: <https://ceae.ro/wp-content/uploads/2017/05/Fundamentarea-abordarii.pdf>
25. CONSILIUL UNIUNII EUROPENE. Recomandarea Consiliului din 22 mai 2018 privind competențele cheie pentru învățarea pe tot parcursul vieții (2018/C 189/01). In: *Jurnalul Oficial al Uniunii Europene*. 2018, C189, pp. 1-13. Available: [https://eur-lex.europa.eu/legal-content/RO/TXT/?uri=CELEX:32018H0604\(01\)](https://eur-lex.europa.eu/legal-content/RO/TXT/?uri=CELEX:32018H0604(01))
26. CONSILIUL UNIUNII EUROPENE. Rezoluția Consiliului privind cadrul strategic pentru cooperarea europeană în domeniul educației și formării în direcția realizării și dezvoltării în continuare a Spațiului european al educației (2021-2030) (2021/C 66/01). In: *Jurnalul Oficial al Uniunii Europene*. 2021, C66, pp. 1-21. Available: [https://eur-lex.europa.eu/legal-content/RO/TXT/HTML/?uri=CELEX:32021G0226\(01\)](https://eur-lex.europa.eu/legal-content/RO/TXT/HTML/?uri=CELEX:32021G0226(01))
27. CRISTEA, S. Educația pentru transformare. In: *Didactica Pro....* 2025, 3-4(151-152), 94-96. Available: <https://doi.org/10.5281/zenodo.16944923>
28. DAVIDENKO, A., BOCANCEA, V. Proiecte STEM/STEAM la fizică. Ghid metodic. Ministerul Educației și Cercetării al Republicii Moldova, Agenția Națională pentru Cercetare și Dezvoltare, Universitatea Pedagogică de Stat „Ion Creangă”. – Chișinău : S. n., 2022 (CEP UPSC). – 62p.
29. DESLAURIERS, L., SCHELEW, E., WIEMAN, C. Improved learning in a large-enrollment physics class. In: *Science*. 2011, 332(6031), 862-864. Available: <https://doi.org/10.1126/science.1201783>
30. EUROPEAN COMMISSION. Boosting STEM participation in tertiary education: A persistent challenge across Europe. European Education Area, 2026. Available: <https://education.ec.europa.eu/resources-and-tools/data-and-analysis-on-education-and-skills/key-trends-in-education/stem-in-tertiary-education>
31. FENSHAM, P. J. Defining an identity: The evolution of science education as a field of research. Springer, 2004.
32. FLORIAN, G., STOENESCU, G. Didactica fizicii (Ed. a III-a, revizuită). București: Editura Didactică și Pedagogică, 2020.
33. FRANȚUZAN, L. Învățarea transformatoare - dimensiune a calității și eficienței procesului educațional la educația științifică (Biologie, Fizică, Chimie). In: *Didactica Pro....* 2018, 3(109), 44-47. Available: https://ibn.idsi.md/sites/default/files/imag_file/44-47_8.pdf

34. GARCIA I GRAU, F., VALLS, C., PIQUÉ, N., RUIZ-MARTÍN, H. Long-term effects of introducing the 5E instructional model on students' conceptual learning. In: International Journal of Science Education. 2021, 43(9), 1441-1458. Available: <https://doi.org/10.1080/09500693.2021.1918354>
35. GATCH, D. Restructuring introductory physics by adapting an active learning studio model. In: International Journal for the Scholarship of Teaching and Learning. 2010, 4(2), Article 14. Available: <https://doi.org/10.20429/ijstl.2010.040214>
36. GIL-PÉREZ, D., GUIASOLA, J., MORENO, A., CACHAPUZ, A., PESSOA DE CARVALHO, A. M., MARTÍNEZ-TORREGROSA, J., SALINAS, J., VALDÉS, P., GONZÁLEZ, E., GENÉ, A., DUMAS-CARRÉ, A., TRICÁRICO, H., GALLEGÓ, R. Defending constructivism in science education. In: Science & Education. 2002, 11(6), 557-571. Available: <https://doi.org/10.1023/A:1019639316456>
37. GUȚU, V., BOLIEV, V. Evaluarea curriculară – evaluarea curriculumului: concept și metodologie. In: Studia Universitatis Moldaviae (Seria Științe ale Educației). 2025, 5(185), 8-16. Available: [https://doi.org/10.59295/sum5\(185\)2025_01](https://doi.org/10.59295/sum5(185)2025_01)
38. HADÎRCĂ, M., ȚÎBULEAC, A. Tendințe globale în educație și impactul lor asupra dezvoltării învățământului din Republica Moldova. In: Acta et Commentationes (Științe ale Educației). 2021, 1(23), 97-105. Available: <https://doi.org/10.36120/2587-3636.v23i1.97-105>
39. HARLEN, W. Taking inquiry-based science education into secondary education. International Academy of Education Science Education Programme, 2010. Available: <https://www.ase.org.uk/bigideas>
40. HATTIE, J. A. C. Hattie's 2017 updated list of factors influencing student achievement. Visible Learning Plus, 2017.
41. HATTIE, J. A. C. Visible learning: A synthesis of over 800 meta-analyses relating to achievement. Routledge, 2008. Available: <https://doi.org/10.4324/9780203887332>
42. HATTIE, J. A. C., DONOGHUE, G. M. Learning strategies: A synthesis and conceptual model. In: npj Science of Learning. 2016, 1, Article 16013. Available: <https://doi.org/10.1038/npjscilearn.2016.13>
43. JOHNSON, D. W., JOHNSON, R. T. Cooperation and competition: Theory and research. Interaction Book Company, 1989.
44. JOIȚA, E., coord. Profesorul și alternativa constructivistă a instruirii: Material suport pedagogic pentru studenții viitori profesori (II). Craiova: Universitatea din Craiova, 2007. Available: http://cis01.central.ucv.ro/DPPD/profesorul%20_si_alternativa_constructivista_a_instruirii.pdf
45. KALENDER, Z. Y., STUMP, E., HUBENIG, K., HOLMES, N. G. Restructuring physics labs to cultivate sense of student agency. In: Physical Review Physics Education Research. 2021, 17(2), Article 020128. Available: <https://doi.org/10.1103/PhysRevPhysEducRes.17.020128>

46. KUHN, T. S. The structure of scientific revolutions. Chicago, IL: University of Chicago Press, 1962.
47. MCDERMOTT, L. C. Physics education research: The key to student learning. In: American Journal of Physics. 2001, 69(11), 1127-1137. Available: <https://doi.org/10.1119/1.1389280>
48. MELTZER, D. E., THORNTON, R. K. Resource letter ALIP-1: Active-learning instruction in physics. In: American Journal of Physics. 2012, 80(6), 478-496. Available: <https://doi.org/10.1119/1.3678299>
49. MINISTERUL EDUCAȚIEI ȘI CERCETĂRII AL REPUBLICII MOLDOVA. Concepția disciplinei școlare Fizică. Astronomie. 2026. Available: <https://drive.google.com/file/d/1IR8-8kuyAIHtXKSnOhS4-6CjOHafZTDi/view>
50. NAILS, D. The people of Plato: A prosopography of Plato and other Socratics. Indianapolis, IN: Hackett Publishing, 2002.
51. NIKAJ, K., GEGA, E., GUZINA, M., IFTI, M. The dynamics of physics student enrollment: A comparative study of Albanian and European universities over the last 20 years. In: The Paris Conference on Education 2025 Official Conference Proceedings. 2025, pp. 909-916. Available: <https://doi.org/10.22492/issn.2758-0962.2025.71>
52. ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD). Future of Education and skills 2030: OECD learning compass 2030. Paris: OECD Publishing, 2019. Available: https://www.oecd.org/content/dam/oecd/en/about/projects/edu/education-2040/concept-notes/OECD_Learning_Compass_2030_concept_note.pdf
53. ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD). PISA 2025 science framework (Draft). Paris: OECD Publishing, 2023. Available: https://pisa-framework.oecd.org/science-2025/assets/docs/PISA_2025_Science_Framework.pdf
54. PERKINS, D. Technology meets constructivism. In: Educational Technology. 1991, 31(9), 19-21.
55. PÎRVU, I., CUCOȘ, C. Actualitatea concepției despre educație a Sfântului Ioan Gură de Aur. In: Revista de Pedagogie. 2023, 71(1), 261-284. Available: <https://doi.org/10.26755/RevPed/2023.1/261>
56. REDISH, E. F., SAUL, J. M., STEINBERG, R. N. On the effectiveness of active-engagement microcomputer-based laboratories. In: American Journal of Physics. 1997, 65(1), 45-54. Available: <https://doi.org/10.1119/1.18498>
57. RODRIGUEZ, L. V., et al. Designing inquiry-based learning environments for quantum physics education in secondary schools. In: Physics Education. 2020, 55(6), Article 065026.
58. RUDOLPH, J. L. How we teach science: What's changed, and why it matters. Cambridge, MA: Harvard University Press, 2019. Available: <https://doi.org/10.4159/9780674240377>

59. SCHMIDT, J. A., ROSENBERG, J. M., BEYMER, P. N. A person-in-context approach to student engagement in science: Examining learning activities and choice. In: Journal of Research in Science Teaching. 2018, 55(1), 19-43.
60. STEIDTMANN, L., KLEICKMANN, T., STEFFENSKY, M. Declining interest in science in lower secondary school: Quasi-experimental and longitudinal evidence on the role of teaching and teaching quality. In: Journal of Research in Science Teaching. 2023, 60(1), 1-33. Available: <https://doi.org/10.1002/tea.21794>
61. UWAMAHORO, J., UWORWABAYEHO, A., NDAYAMBAJE, I., NSENGIMANA, T. Physics laboratory activities and students' conceptual understanding of physics concepts: Evidence from secondary schools. In: Journal of Baltic Science Education. 2021, 20(4), 648-662.
62. WALSH, C., LEWANDOWSKI, H. J., HOLMES, N. G. Skills-focused lab instruction improves critical thinking skills and experimentation views for all students. In: Physical Review Physics Education Research. 2022, 18(1), Article 010128. Available: <https://doi.org/10.1103/PhysRevPhysEducRes.18.010128>
63. WHITE, S., CHU, R. Y., OMAN, J. Has the number of students taking physics in US high schools declined? Preliminary results from the 2023-2024 nationwide survey of high school physics. In: Physics Today. 2025. Available: <https://doi.org/10.1063/pt.6.3.20250310a>
64. **ZELENSCHI, I.** Evoluția și analiza comparativă a paradigmelor educaționale. In: Univers Pedagogic, 2025, nr. 4(88), pp. 91-98. ISSN 1811-5470. <https://doi.org/10.52387/1811-5470.2025.4.12>
65. **ZELENSCHI, I.** Premise constructiviste în noua concepție a disciplinei Fizică și Astronomie. In: Perspective interdisciplinare asupra cunoașterii, 8 mai 2026, Chișinău UPSC, pp. 134-139. ISBN 978-9975-48-419-0. <https://doi.org/10.46727/c.08-05-2026.p134-139>
66. **ZELENSCHI, I., CALALB, M.** Applying the flipped classroom method in studying rotational equilibrium in 7th grade physics. In: Studia Universitatis Moldaviae (Seria Științe ale Educației), 2024, nr. 9(179), pp. 217-223. ISSN 1857-2103. [https://doi.org/10.59295/sum9\(176\)2024_31](https://doi.org/10.59295/sum9(176)2024_31)
67. ДАВИДЕНКО, А. А. Методика розвитку творчих здібностей учнів у процесі навчання фізики (теоретичні основи). Ніжин: ТОВ “Видавництво “Аспект Поліграф”, 2004. – 264 с.
68. ДАВИДЕНКО, А. Роль информационно-коммуникационных технологий в учебном процессе по физике. In: Acta et commentationes (Științe ale Educației), 2021, nr. 4(26), pp. 17-27. ISSN 1857-0623. DOI: <https://doi.org/10.36120/2587-3636.v26i4.17-27>

LIST OF THE AUTHOR'S PUBLICATIONS ON THE THESIS TOPIC

Articles in international journals

1. Calalb, M., **Zelenschi, I.** (2024). The Effects of Constructivist Physics Lessons and Laboratories on Students' Academic Success. In: Acta Didactica Napocensia, 17(2), 99-111. <https://doi.org/10.24193/adn.17.2.8>

Articles in national journals

2. **Zelenschi, I.**, Calalb, M. (2024). Applying the flipped classroom method in studying rotational equilibrium in 7th grade physics. In: Studia Universitatis Moldaviae (Seria Științe ale Educației), 9(179), 217-223. ISSN 1857-2103. [https://doi.org/10.59295/sum9\(176\)2024_31](https://doi.org/10.59295/sum9(176)2024_31)
3. Calalb, M., **Zelenschi, I.** (2023). Constructivismul în predarea fizicii. In: Acta et Commentationes, Sciences of Education, 3(33), 76-85. ISSN 1857-0623, E-ISSN 2587-3636. <https://doi.org/10.36120/2587-3636.v33i3.76-85>
4. **Zelenschi, I.** (2025). Evoluția și analiza comparativă a paradigmelor educaționale. In: Univers Pedagogic, 4(88), 91-98. ISSN 1811-5470. <https://doi.org/10.52387/1811-5470.2025.4.12>

Articles in proceedings of international conferences in the Republic of Moldova

5. **Zelenschi, I.** (2026). Premise constructiviste în noua concepție a disciplinei Fizică și Astronomie. In: Perspective interdisciplinare asupra cunoașterii, 8 mai 2026, Chișinău: UPSC, pp. 139-144. ISBN 978-9975-48-419-0. <https://doi.org/10.46727/c.08-05-2026.p134-139>
6. Calalb, M., Dabija, V., **Zelenschi, I.** (2024). Integrating Black Holes and Gravitational Waves into School Physics. In: Învățare activă pentru dezvoltare durabilă, 15 noiembrie 2024, Chișinău. Chișinău, Republica Moldova: CEP UPS "I. Creangă", pp. 34-44. ISBN 978-9975-46-989-0. <https://doi.org/10.46727/c.15-11-2024.p34-44>
7. Calalb, M., **Zelenschi, I.** (2024). Impactul lucrărilor de laborator asupra rezultatelor evaluării sumative la studierea electrocineticii în clasa a VIII-a. In: Perspective interdisciplinare asupra predării și învățării științelor, 25 aprilie 2024, Chișinău. Chișinău: CEP UPS "I. Creangă", pp. 233-244. ISBN 978-9975-46-933-3. <https://doi.org/10.46727/c.25-04-2024.p233-244>
8. Calalb, M., **Zelenschi, I.** (2023). Modele de medii constructiviste de învățare a fizicii. In: Science and education: new approaches and perspectives, Ed. 25, 24-25 martie 2023, Chișinău. Chișinău: CEP UPSC, Seria 25, Vol. 3, pp. 346-352. ISBN 978-9975-46-787-2. <https://doi.org/10.46727/c.v3.24-25-03-2023.p346-352>
9. Calalb, M., **Zelenschi, I.** (2022). Metode constructiviste de predare a interacțiunilor în clasa VII. Analiză comparativă. In: Abordări inter/transdisciplinare în predarea științelor reale

(concept STEAM), Ediția a 2-a, 28-29 octombrie 2022, Chișinău. Tipografia UST, pp. 388-393. ISBN 978-9975-76-411-7. https://ibn.idsi.md/sites/default/files/imag_file/388-393_3.pdf

Articles in proceedings of national conferences in the Republic of Moldova

10. Calalb, M., Zelenschi, I. (2022). Abordări constructiviste la lecția de fizică. In: Materialele Conferinței Republicane a Cadrelor Didactice: Didactica științelor exacte, 26-27 februarie 2022, Chișinău. Chișinău: Tipografia Universității de Stat din Tiraspol, Vol. 1, pp. 264-268. ISBN 978-9975-76-382-0. https://ibn.idsi.md/sites/default/files/imag_file/p-264-268_1.pdf

ABSTRACT
Irina Zelenschi

Development and Application of Modern Constructivist Concepts in Physics Education
Doctoral dissertation in Education Sciences. Chişinău, 2026

Dissertation structure: The dissertation consists of an introduction, three chapters, general conclusions and recommendations, and a bibliography comprising 214 references. The thesis contains 140 pages of main text, 31 tables, 18 figures and 13 annexes. The research results have been published in 10 scientific papers.

Keywords: educational constructivism, conceptual understanding, inquiry-based learning, metacognition, physics teaching.

The aim of the research is to determine the theoretical, methodological, and didactic foundations of constructivist physics learning and to validate them empirically under authentic classroom conditions.

Research objectives: (1) to analyze the theoretical and didactic foundations of constructivism in physics education; (2) to model and hierarchically classify educational paradigms according to their effect size on learning; (3) to design a methodological framework for physics lessons based on constructivist principles through the integration of instructional strategies with demonstrated effect sizes; (4) to empirically validate the impact of constructivist instructional organization on the achievement of lower and upper secondary school students; (5) to examine the functioning of constructivism within the national curriculum and identify the limits of its implementation; (6) to explore the epistemic characteristics of modern physics content and their implications for knowledge construction.

Scientific novelty and originality consist of: (1) proposing a hierarchy of constructivist educational paradigms based on effect size; (2) formulating the operational triad of constructivist learning—cognitive effort, prior knowledge, and metacognition; (3) empirically validating constructivist instructional strategies in Moldovan schools; (4) demonstrating that the epistemic nature of modern physics inherently requires a constructivist instructional approach.

The research outcome contributes to operationalizing constructivism in physics teaching, showing theoretically and empirically that learning centered on students' cognitive effort, metacognition, and systematic feedback fosters conceptual understanding and higher academic performance.

The theoretical significance of the study lies in establishing a theoretical framework for constructivism in physics education by integrating educational paradigms, cognitive mechanisms, and instructional models into a coherent conceptual vision.

The practical value of the dissertation consists in providing physics teachers with empirically validated constructivist lesson models, laboratory activities, and a framework for the analysis of curriculum documents.

Implementation of the scientific results was carried out through educational activities with students of the *Hyperion* Theoretical High School in Chişinău, as well as through scientific conferences and publications.

ADNOTARE
Zelenschi Irina

Dezvoltarea și aplicarea conceptelor constructiviste moderne în predarea fizicii

Teză de doctor în științe ale educației. Chișinău, 2026

Structura tezei: Teza este alcătuită din introducere, 3 capitole, concluzii generale și recomandări, bibliografie (214 surse). Lucrarea conține 140 de pagini de text de bază, 31 tabele, 18 figuri, 13 anexe. Rezultatele sunt publicate în 10 lucrări științifice.

Cuvinte-cheie: constructivism didactic, înțelegere conceptuală, învățare prin cercetare, metacogniție, predarea fizicii.

Scopul lucrării constă în determinarea premiselor teoretice, metodologice și didactice ale organizării învățării constructiviste a fizicii, validate empiric în condiții reale de predare.

Obiectivele cercetării: 1) analiza fundamentelor teoretico-didactice ale constructivismului în predarea fizicii; 2) modelarea și ierarhizarea paradigmatelor educaționale în funcție de efectul lor asupra învățării; 3) proiectarea metodologică a lecției de fizică pe baza principiilor constructiviste, prin integrarea strategiilor didactice cu mărimea efectului demonstrată; 4) validarea empirică a impactului organizării constructiviste asupra performanței elevilor din gimnaziu și liceu; 5) examinarea funcționării constructivismului în cadrul curricular național și identificarea limitelor aplicării sale; 6) explorarea specificului epistemic al conținuturilor de fizică modernă și a implicațiilor acestuia asupra construirii cunoașterii.

Noutatea și originalitatea științifică constă în: 1) propunerea scării paradigmatelor educaționale constructiviste ierarhizate după mărimea efectului; 2) formularea triadei operaționale a învățării constructiviste: efort cognitiv, cunoștințe anterioare și metacogniție; 3) validarea empirică a strategiilor constructiviste în școala moldovenească; 4) demonstrarea că fizica modernă impune, prin natura sa epistemică, un demers didactic constructivist.

Rezultatul obținut contribuie la soluționarea problemei operaționalizării constructivismului în predarea fizicii, evidențiind teoretic și empiric asocierea organizării învățării centrate pe efortul cognitiv al elevului, pe metacogniție și pe feedback sistematic cu înțelegerea conceptuală și performanța academică.

Semnificația teoretică a cercetării: se fundamentează un cadru teoretic al constructivismului aplicat la fizică, articulând paradigme educaționale, mecanisme cognitive și modele didactice într-o viziune unitară.

Valoarea aplicativă a lucrării constă în oferirea pentru profesorii de fizică a unor modele de lecții constructiviste, lucrări de laborator validate empiric și un cadru de analiză a documentelor curriculare.

Implementarea rezultatelor științifice a fost realizată în cadrul activităților educaționale cu elevii Liceului Teoretic „Hyperion” din mun. Chișinău, precum și prin intermediul conferințelor și publicațiilor științifice.

АННОТАЦИЯ

Зеленски Ирина

Разработка и применение современных конструктивистских концепций в преподавании физики

Диссертация на соискание ученой степени доктора педагогических наук

Кишинёв, 2026

Структура диссертации: Диссертация состоит из введения, 3 глав, общих выводов и рекомендаций, библиографии (214 источников). Работа содержит 140 страниц основного текста, 31 таблиц, 18 рисунков, 13 приложений. Результаты опубликованы в 10 научных работах.

Ключевые слова: дидактический конструктивизм, концептуальное понимание, исследовательское обучение, метакогниция, преподавание физики.

Цель исследования состоит в определении теоретических, методологических и дидактических предпосылок организации конструктивистского обучения физике, эмпирически апробированных в реальных условиях преподавания.

Задачи исследования: 1) анализ теоретико-дидактических основ конструктивизма в преподавании физики; 2) моделирование и иерархизация образовательных парадигм в зависимости от их влияния на обучение; 3) методическая разработка урока физики на основе конструктивистских принципов путём интеграции дидактических стратегий с доказанной величиной эффекта; 4) эмпирическая проверка влияния конструктивистской организации обучения на успеваемость учащихся гимназии и лицея; 5) изучение функционирования конструктивизма в рамках национальной учебной программы и выявление ограничений его применения; 6) исследование гносеологической специфики содержания современной физики и её последствий для формирования знания.

Научная новизна и оригинальность исследования заключается в: 1) разработке шкалы конструктивистских образовательных парадигм, ранжированных по величине эффекта; 2) формулировании функциональной триады конструктивистского обучения: когнитивное усилие, предварительные знания и метакогниция; 3) эмпирической апробации конструктивистских стратегий в молдавской школе; 4) доказательстве того, что современная физика в силу своей гносеологической природы требует конструктивистского дидактического подхода.

Полученный результат операционализации конструктивизма в преподавании физики, теоретически и эмпирически показывая, что обучение, основанное на когнитивных усилиях учащихся, метакогниции и систематической обратной связи, способствует концептуальному пониманию и более высокой академической успеваемости.

Теоретическая значимость исследования: обосновывается теоретическая база конструктивизма применительно к физике, объединяющая образовательные парадигмы, когнитивные механизмы и дидактические модели в единую концепцию.

Прикладная ценность работы заключается в предоставлении учителям физики моделей конструктивистских уроков, эмпирически апробированных лабораторных работ и инструментария для анализа программных документов.

Внедрение научных результатов осуществлялось в рамках образовательной деятельности с учащимися Теоретического лицея «Hurperion» г. Кишинёва, а также через научные конференции и публикации.

ZELENSCHI IRINA

**DEVELOPMENT AND APPLICATION OF MODERN
CONSTRUCTIVIST CONCEPTS IN PHYSICS TEACHING**

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