"ION CREANGĂ" STATE PEDAGOGICAL UNIVERSITY OF CHIȘINĂU

With manuscript title
C.Z.U: 37.091:52(043.2)=111

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DEVELOPING INVESTIGATIVE COMPETENCE IN GIFTED STUDENTS THROUGH EXTRACURRICULAR ASTRONOMY ACTIVITIES

Specialisation 532.02 – School Didactics
by Levels and Subjects

SUMMARY
of the doctoral thesis in Educational Sciences

CHIȘINĂU, 2025

The thesis was developed within the Doctoral School of "Educational Sciences" at "Ion Creangă" State Pedagogical University of Chișinău

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The public defence of the thesis is scheduled for **March 28th, 2025, at 15:00**, at "Ion Creangă" State Pedagogical University, Room 206, Study Block No. 7, 5 Ghenadie Iablocikin Street, MD-2069.

The doctoral thesis and summary can be accessed on the website of "Ion Creangă" State Pedagogical University of Chișinău (www.upsc.md) and on the ANACEC website (www.anacec.md).
The summary was sent on February 25th, 2025.

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List of Abbreviations:
NGO – Non-Governmental Organisation
ERR – Elicit-Realise-Reflect
SPSS – Statistical Package for the Social Sciences
STEM – Science, Technology, Engineering, and Mathematics

CONCEPTUAL FRAMEWORK OF THE RESEARCH

Relevance and Importance of the Topic. The 21st century marks a distinct phase in human society's progress. The rapid advancement of science and technology is directly based on economic competition between nations, thus requiring a new and pragmatic approach to both formal and non-formal education.

Regarding the Council of the European Union Recommendation of 22 May 2018 on key competencies for lifelong learning, certain competencies can be identified as having a significant connection with the research conducted in this doctoral thesis. These key competencies are: competencies in science, technology, engineering, and mathematics (STEM), as well as digital competencies [20, p. 7].

The relevance and importance of the topic are also found in the Education Code of the Republic of Moldova, where Article 11 (1) states that the purpose of education is to develop a system of competencies which, once acquired by the individual, help them actively participate in social and economic life [5].

Article 11 (2) also specifies the key competencies that should be formed upon completing the educational process. Two of these are closely linked to the doctoral research topic: competence in mathematics, science, and technology and digital competence.

Description of the Situation in the Research Field, Presentation of Previous Research Results. The approach to the concept of investigative competence in the context of student competence development has been analysed in various studies from the Republic of Moldova and Romania.

Contributions to the analysis of this concept within the educational process have been made by several authors, including A. Ardelean and O. Mândruț [1], A. Gremalschi [11], as well as numerous articles written by L. Franțuzan, L. Zota [9], C. Barbăroș [2], L. Sclifos [21], and others. At the international level, the works of J. Percy [19], P. Blessinger and J. M. Carfora [3] are worth mentioning. These specialists have dedicated their studies to researching investigative competence and its development in astronomy classes.

In the specialised literature, there are numerous debates on defining and identifying gifted students, with this topic being addressed by many researchers. In this context, we mention T. Kettler [15], S. N. Kaplan [14], C. L. Weber and L. Stanley [33], J. F. Smutny [22], S. E. von Fremd [23], C. Boswell [34], etc.

Following the analysis of studies conducted on investigative competence in gifted students within the context of extracurricular activities, the following contradictions were identified:

- In the Republic of Moldova and Romania, there is no established methodology for forming investigative competence in gifted students through extracurricular astronomy activities.
- In the Republic of Moldova, there are no extracurricular astronomy activities in which gifted students are involved in the formation and development of investigative competence.

- In the Republic of Moldova, there are no sufficiently trained teachers in the field of astronomy who can conduct astronomical observations with students, especially gifted students in extracurricular activities.

The identified contradictions have led to the formulation of the following **research problem**: What is the methodology for developing investigative competence in gifted students through extracurricular astronomy activities?

The aim of the research is to provide a theoretical and praxeological foundation for investigative competence, as well as to develop and experimentally validate a pedagogical model for fostering investigative competence in gifted students through extracurricular astronomy activities.

Research objectives:

- To analyse fundamental theoretical concepts related to the definition and necessity of developing investigative competence in gifted students through extracurricular astronomy activities.
- To determine the methodological foundations for developing investigative competence in gifted students.
- To develop and experimentally validate a pedagogical model for fostering investigative competence in gifted students through extracurricular astronomy activities.

Synthesis of the research methodology and justification of the chosen research methods:

- Theoretical methods: analysis, synthesis, comparison, and theoretical modelling.
- Praxeological methods: testing and surveys.
- Pedagogical experiment: included different types of experiments, such as diagnostic, formative, and control experiments.
- Astronomical observations: conducting astrometric and photometric observations.
- Reduction and analysis of astrometric and photometric data.
- Mathematical-statistical methods for processing and analysing data obtained from the pedagogical experiment.

The novelty and scientific originality of the research lie in the development of the methodology and pedagogical model for fostering investigative competence in gifted students through extracurricular astronomy activities.

The solved scientific problem consists of the theoretical and methodological foundation for developing investigative competence in gifted students through extracurricular astronomy activities. It addresses a series of interconnected aspects from the fields of educational sciences and astronomy. This competence is essential in preparing young individuals to become future scientific researchers.

The research's theoretical significance lies in its contribution to understanding the process of developing investigative competence within extracurricular astronomy activities and in expanding the existing body of knowledge in the field of pedagogy.

This extends beyond the educational sphere, having profound implications for the advancement of human knowledge and the preparation of a new generation of young people to face the challenges and opportunities in the field of astronomy and related sciences.

Main scientific results submitted to support the thesis:

- Development and implementation of a Pedagogical Model for fostering investigative competence in gifted students through extracurricular astronomy activities, based on constructivist approaches.
- Development and implementation of a Methodology for the formation of investigative competence in gifted students within extracurricular astronomy activities.
- Experimental validation of the effectiveness of the pedagogical model and the developed methodology.

Implementation of scientific results was achieved through the experimental validation of the methodology and pedagogical model for developing investigative competence in gifted students within extracurricular astronomy activities. These activities were conducted at the Astronomical Observatory of the Natural Sciences Museum Complex "Răsvan Angheluță" in Galați. Additionally, the developed methodology and pedagogical model were integrated into extracurricular activities organised at the Astronomical Observatory of the Technical University of Moldova.

Approval of research results. The research results were reviewed and endorsed during the meetings of the Doctoral Dissertation Advisory Committee at the Doctoral School of Educational Sciences, "Ion Creangă" State Pedagogical University of Chișinău. Moreover, the key research findings were published in various scientific journals and conference proceedings, which can be found in the author's list of publications on the dissertation topic in this summary.

Furthermore, the research findings were presented and communicated in the following academic and public scientific events with expert audiences:

- "Extracurricular Astronomy Education Activities," Interdisciplinary Conference "Science and Education," Danubius University, Galați, 25 March 2022;
- "Developing Investigative Competence in Students through Astronomical Observations," National Scientific Communication Session, 17th Edition, "Vasile Pârvan" Museum, Bârlad, 12-14 May 2022;
- "Observing Variable Stars as an Extracurricular Activity for Developing Scientific Research Competence in Students," ASTRO 2022 – National Astronomy Conference and Camp, Târgoviște and Runcu Stone, 21-27 October 2022;
- "The Role of Extracurricular Astronomy Activities in Non-Formal Education," Non-Formal Education Conference, 1st Edition, Danubius University, Galați, 8 December 2022;

- "Online Extracurricular Astronomy Activities," International Scientific Communication Session, 18th Edition, "Vasile Pârvan" Museum, Bârlad, 19-20 May 2023;
- "The Role of Automation in the Formation of Research Competence in Gifted Students within Extracurricular Astronomy Activities," International Conference "Innovative Manufacturing Engineering & Energy," 27th Edition, Technical University of Moldova, 12-14 October 2023;
- "Extracurricular Education at the Astronomical Observatory of the Natural Sciences Museum Complex "Răsvan Angheluță Galați," ASTRO-FEST 2023 Astronomy Festival, Romanian Meteor Astronomical Society, Târgoviște, 18-21 October 2023;
- "Developing Investigative Competence through Extracurricular Astronomy Activities," Scientific-Methodological Seminar "Current Issues in Teaching, Learning, and Evaluating Physics in General Education," "Ion Creangă" State Pedagogical University of Chișinău, 7 March 2024;
- "The Contribution of Investigative Competence to the Development of Gifted Students through Extracurricular Astronomy Activities," International Scientific Communication Session, 19th Edition, "Vasile Pârvan" Museum, Bârlad, 10-11 May 2024;
- "Teaching Astronomy in Romanian Territories in Relation to Its Historical Background," Symposium "Nicolae Donici and Astronomy in Moldovan Territories," Romanian Academy, Academy of Sciences of Moldova, and the Astronomical Institute of the Romanian Academy, 11 September 2024.

Publications on the Topic of the Doctoral Thesis: 9 scientific papers, including: 2 articles in scientific journals indexed in the Web of Science and SCOPUS databases, 3 articles in specialised journals, 4 articles in the proceedings of national and international conferences published in the Republic of Moldova.

Structure of the Thesis: Introduction, three chapters, general conclusions and recommendations, bibliography comprising 239 titles, 154 pages of main text, 46 figures, 5 tables, 34 appendices.

Keywords: investigative competence, gifted students, extracurricular activities, astronomy, pedagogical model for the development of investigative competence, methodology for the development of investigative competence.

CONTENT OF THE THESIS

In **Chapter 1. Theoretical-didactic Approaches Regarding the Necessity of Developing the Investigative Competence of Gifted students within Extracurricular Astronomy Activities**, a theoretical and critical analysis of the concepts of competence, investigation, scientific research, investigative competence, scientific investigation, gifted students, and extracurricular activities, are presented.

Within *the Framework of the National Curriculum of the Republic of Moldova*, the concept of competence is defined as "a transferable and multifunctional package of

knowledge, capacities, skills, abilities, values, and attitudes that enable the individual to achieve personal fulfilment and professional development, social inclusion, and professional integration in the respective field" [12, p. 18].

In the specialised literature, an investigation is understood as "the intentional process of diagnosing situations, formulating problems, criticising experiments and distinguishing alternatives, planning investigations, researching conjectures, seeking information, constructing models, debating with peers using evidence and representations, and forming coherent arguments" [6, p. 1].

Investigative competence is fundamental in the field of observational astronomy. It involves knowledge, capacities, skills, and abilities in operating telescopes and other observational equipment.

Competence encompasses scientific curiosity, methodological rigour, analytical skills, and creativity in interpreting scientific data, as well as presenting research in the field of astronomy [27, p. 111].

From another perspective, investigative competence consists of the's ability and capacity to integrate information from various disciplines, allowing them to interpret, analyse, formulate personal opinions, and use information to solve specific problems.

To develop this competence, the teacher must awaken children's curiosity, select appropriate content, encourage the expression and argumentation of opinions, and facilitate the presentation of information to peers, supporting collaboration and teamwork [13, p. 293].

In simple terms, gifted/highly gifted students are those who demonstrate superior performance in a specific domain compared to the performance of their peers of the same age.

In English, the term *gifted children* covers a broad spectrum of situations and, in most cases, simply refers to a child with remarkable intellectual structures and aptitudes, regardless of the field.

In fact, within the Anglo-Saxon sphere, no clear distinction is made between giftedness and high giftedness, and, as we shall see, in our context, these terms are also used without a well-defined distinction. In the local literature, a preference for the phrase "gifted/highly gifted children" has been observed.

Many times, international debates related to this subject are contradictory, and there are multiple camps among specialists.

Depending on their school of thought, specialists use dozens of definitions, and this situation arises from the fact that intelligence is not a unitary concept; rather, multiple types of intelligence exist, and therefore, it is difficult to rely on a single definition to explain this complex concept.

Some specialists indicate that in psychology and pedagogy, there are two approaches to the idea of giftedness/high giftedness among children.

One approach starts from the premise that all children are gifted, but this fact is not always manifested.

As such, the teacher has the task of discovering and developing the abilities of each child individually. The second approach is based on the idea that only some children

are endowed with a range of remarkable abilities. From the perspective of the proponents of this viewpoint, these children become the intellectual and creative elite of humanity, and they must be discovered to encourage the development of their abilities through as many means as possible [10, p. 2].

Extracurricular activities can be academic or non-academic, funded by non-governmental organisations (NGOs) or state institutions, and can take place outside the school environment or even within the school premises but outside compulsory class hours, and they are not part of the curriculum [8, p. 481].

The fact that these activities can be organised within the school setting or by other institutions is often emphasised in the literature, a point also highlighted in our context by Constantin Cucoș [7, p. 304], among others.

Additionally, this chapter presents an analysis of the state of astronomy education in Romania, the Republic of Moldova, and neighbouring countries.

In Romania, formal education in astronomy is not offered as a specialised course at the school level. However, in the past, astronomy was taught at the high school level, using various textbooks for instruction.

Currently, knowledge related to astronomy is integrated into the school curriculum within geography, mathematics, and physics lessons, from primary education to high school.

Astronomy education in Romania is mainly facilitated through non-formal, extracurricular activities [31, p.148].

In the Republic of Moldova, an introduction to astronomy begins as early as kindergarten, through programmes such as "Recognising certain celestial bodies" for children aged 3-5 years and "Identifying and describing celestial bodies" for children aged 5-7 years.

In primary schools, the subject is included in Science in the second grade, with five hours dedicated to studying celestial bodies. In Geography in the fifth grade, the Earth's movements around its axis and the Sun are studied, while in Physics in the sixth grade, there is a session on studying solar and lunar eclipses [Ibidem, pp.148-149].

In the twelfth grade, 20 hours are allocated to the "Elements of Astronomy" chapter from the Physics. Astronomy textbook [4].

This chapter analyses the role of curiosity in learning and research and the importance of extracurricular activities in developing investigative competence in gifted students.

Chapter 2. The Methodology of Developing Investigative Competence in Gifted students through Extracurricular Astronomy Activities focuses on presenting the methodology for developing the competence units required for astronomical investigations. Additionally, the tools used in astronomical observations necessary for extracurricular activities are described, along with concepts related to observational astronomy. Furthermore, this chapter presents several methodologies for astronomical observation.

The methodology of astrometric observations of asteroids and comets includes the following educational objectives:

- Acquiring knowledge and skills for conducting astrometric observations of asteroids and comets;
- Developing the abilities and skills necessary for reducing and analysing astrometric data.

Methodology of Astrometric Observations of Double Stars:

- Acquiring knowledge and skills for conducting astrometric observations of double stars;
- Developing the abilities and skills necessary for reducing and analysing astrometric data.

Methodology of Photometric Observations of Variable Stars:

- Acquiring knowledge and skills for conducting photometric observations of variable stars;
- Developing the abilities and skills necessary for reducing photometric data and analysing light curves.

Methodology of Photometric Observation of Exoplanet Transits:

- Acquiring knowledge and skills for conducting photometric observations of exoplanet transits;
- Developing the abilities and skills necessary for reducing and analysing photometric data.

Methodology of Detecting and Observing Supernovae:

- Acquiring knowledge and skills for detecting supernovae;
- Acquiring knowledge and skills for conducting astrometric and photometric observations of supernovae;
- Developing the abilities and skills necessary for reducing and analysing astrometric and photometric data.

Additionally, this chapter outlines the theoretical benchmarks that formed the foundation for developing the Pedagogical Model for Developing Investigative Competence in Gifted students through Extracurricular Astronomy Activities.

The core of the proposed pedagogical model is based on the ERR framework (Evocation - Realisation of Meaning - Reflection).

This framework enables children to consolidate and build their competencies and knowledge through investigation [18, pp. 200-202].

Through the ERR framework, active learning is stimulated by establishing connections between prior knowledge and new knowledge.

Prior knowledge may be naive or pre-scientific, while new knowledge is acquired through systematic study of the respective science [17, p. 348].

The main feature of the pedagogical model based on investigation is that it is child-centred; learning is self-directed, the child is actively involved in the learning process, and the teacher acts merely as a facilitator, providing guidance throughout the process.

This approach is grounded in the principles articulated by the constructivist movement (Figure 2.1).

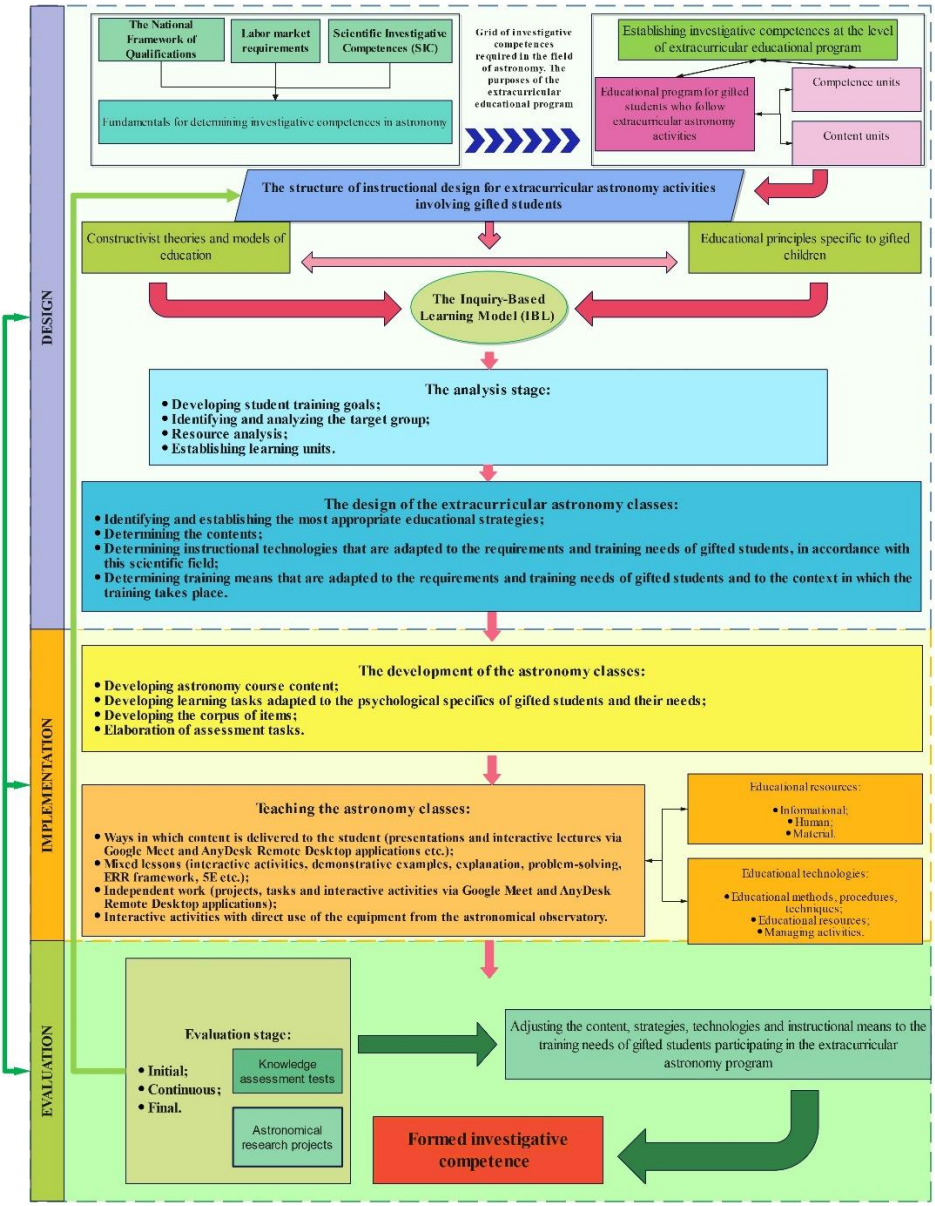

Figure 2.1. The Pedagogical Model for developing investigative competence in gifted students through extracurricular astronomy activities

Chapter 3. Experimental Validation of the Pedagogical Model for Developing Investigative Competence in Gifted students through Extracurricular Astronomy Activities. This chapter presents the design and implementation of the pedagogical experiment for assessment, training, and validation. The objectives of the pedagogical assessment experiment were as follows: Identifying gifted students to participate in extracurricular astronomy activities; Administering an assessment questionnaire to determine the level of investigative competence development in the selected gifted students.

Within the pedagogical assessment experiment, research methods such as testing, questionnaires, comparison, data analysis obtained through tests and questionnaires, and qualitative interpretation were employed.

Research Methodology. The pedagogical assessment experiment included the following stages:

- Development of an evaluation tool (test) to identify gifted students for participation in extracurricular astronomy activities.
- Application of the evaluation tool, selection of gifted students, and establishment of two samples (experimental group and control group).
- Development of an assessment questionnaire to evaluate the level of investigative competence development in the gifted students from both groups (experimental and control).
- Experimental application of the assessment questionnaire to determine the level of investigative competence development in the selected gifted students from the experimental and control groups.

The test for identifying gifted students for participation in extracurricular astronomy activities was distributed online (via social media, WhatsApp, Viber, email, etc.) to physics teachers in middle schools, high schools, and colleges in Romania and the Republic of Moldova.

Subsequently, physics teachers distributed the test only to students in grades VI – XII who, based on teachers' observations during school lessons, were identified as exhibiting characteristics such as exceptional talent and aptitude in physics, superior performance compared to other students in their class, heightened creativity and intuition in problem-solving, motivation and interest in learning physics, the ability to learn rapidly and retain information easily, keen observational skills in physics experiments, experimental abilities in the field of physics, and a sense of responsibility in completing tasks during physics lessons, among other traits [27, p. 111], [29, p. 140-141].

Using this method, the test was distributed to students in grades VI-XII in Romania and the Republic of Moldova to establish the samples for conducting the pedagogical experiment. This study included a total of 327 participants from Romania and the Republic of Moldova.

The distribution of students across different educational institutions in Romania, based on the data collected through the test, is presented in Figure 3.1.

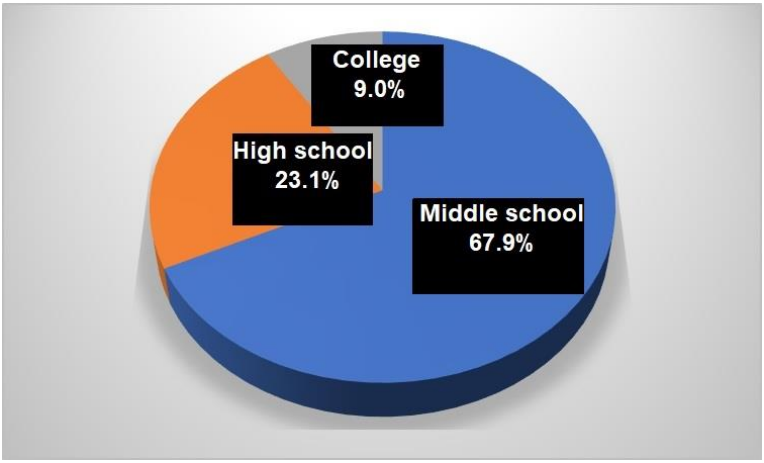

Fig. 3.1. Distribution of students by educational institutions in Romania

The distribution of students across different educational institutions in the Republic of Moldova, based on the data collected through the test, is presented in Fig. 3.2.

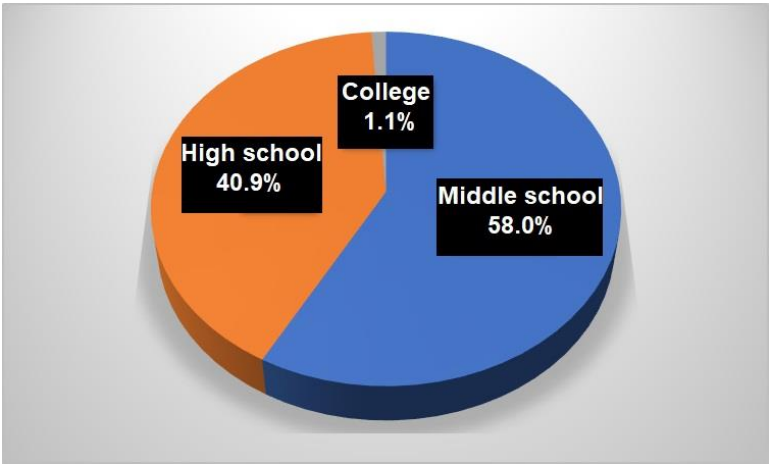

Fig. 3.2. Distribution of students by educational institutions in the Republic of Moldova

The test was structured based on a set of items, each associated with multiple response options.

The purpose of this approach was to identify a broad spectrum of characteristics necessary for gifted students to participate in extracurricular astronomy activities [27, p. 111], [29, p. 141].

Characteristics targeted in the research among students were as follows: The ability to concentrate on a subject for an extended period; The ability to engage in a project

requiring investigation without seeking guidance from a teacher; The ability to work persistently towards achieving a goal even in the face of failures; The ability to learn at a fast pace and retain information easily; Observational skills; Taking responsibility for completing tasks; The ability to learn how to use new software without a teacher's help; Impatience and interest in exploring the possibilities of using new software; Passion and curiosity for developing the necessary skills to use new software; Curiosity about scientific methods; The ability to explore scientific topics creatively in discussions; Enthusiasm during debates on various scientific topics; The ability to interpret scientific data; Passion, curiosity, and perseverance in seeking out information that is difficult to understand in the field of astronomy [26, p. 439].

For each item, the response options were designed to reflect different levels of abilities or attitudes, each response being assigned a specific score.

The test was applied through Google Forms/Formfacade, which allowed for the efficient creation and management of questions and responses in an online format [36].

The selection of gifted students for participation in extracurricular astronomy activities was conducted based on the score obtained by each student on the test.

The top 55 students from the list generated for the Republic of Moldova formed the experimental group, and the top 55 students from the list generated for Romania formed the control group. The structure of the experimental sample is presented in Table 3.1.

Table 3.1. Structure of the experimental sample

Sample type	**Number and categories of participants**	**Research stages applied**			**Total sample**
Experimental Group	Republic of Moldova: 55 students from grades VI-XII	Assessment October 2022 – January 2023	Training February – August 2023	Validation September – December 2023	110 subjects
Control Group	Romania: 55 students from grades VI-XII	Assessment October 2022 – January 2023	Training February – August 2023	Validation September – December 2023	

Next, the research methodology for the pedagogical assessment experiment is presented in Table 3.2.

Table 3.2. Research methodology for the pedagogical assessment experiment

Sample type	Number and categories of participants	Research methods
Experimental Group	Republic of Moldova: 55 students from grades VI-XII	Questionnaire
Control Group	Romania: 55 students from grades VI-XII	Questionnaire

In the pedagogical assessment experiment, the questionnaire was designed to identify the level of investigative competence development in the selected gifted students.

During the research, eight items were analysed in the assessment and validation stages, evaluating students' knowledge, capacities, skills, habits, and attitudes from both the experimental and control groups in the field of observational astronomy.

To illustrate the results obtained in the assessment stage, two representative items were selected.

These reflect the key aspects examined in the research and highlight the differences observed between the experimental and control groups.

Item 3: How well do you understand how astrometric and photometric observations are conducted?

The distribution of responses to Item 3 for each research group is presented in Figure 3.3.

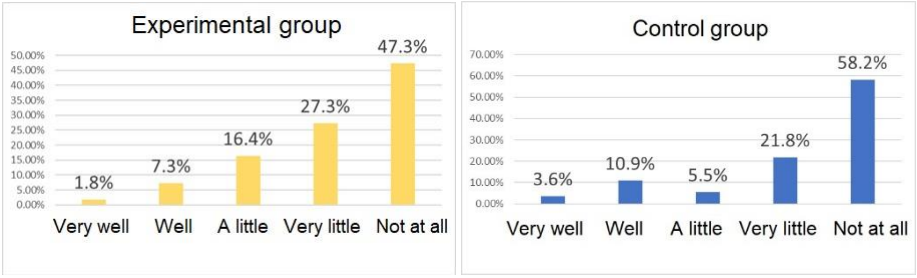

Fig. 3.3. Distribution of responses to item No. 3 for each research group

Item 5: Have you used software for obtaining and analysing astrometric and photometric data before?

The distribution of responses to Item No. 5 for each research group can be viewed in Figure 3.4.

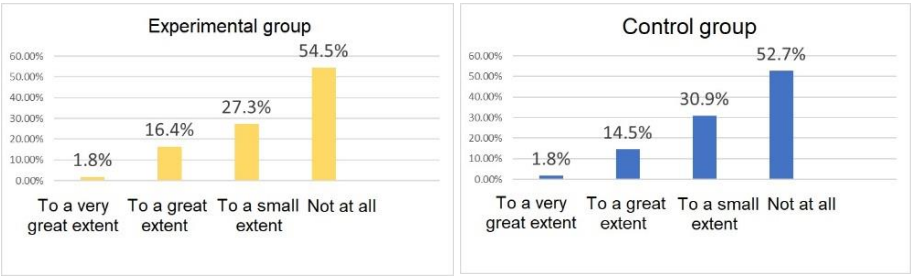

Fig. 3.4. Distribution of responses to item No. 5 for each research group

The following presents the results obtained from the application of the assessment questionnaire: To the question, "To what extent do you possess knowledge about the necessary tools (telescope and camera) for conducting astrometric and photometric observations?", the students in the experimental group answered as follows: 1.8% "To a very great extent", 18.2% "To a great extent", 41.8% "To a small extent", and 38.2% "Not at all". In the control group, the students' responses were as follows: 0.0% "To a very great extent", 21.8% "To a great extent", 36.4% "To a small extent", and 41.8% "Not at all".

To the question, "Do you know how software can be used for obtaining and analysing astrometric and photometric data?", the students in the experimental group answered as follows: 1.8% "Very well", 9.1% "Well", 14.5% "A little", 27.3% "Very little", and 47.3% "Not at all". In the control group, the students' responses were as follows: 1.8% "Very well", 10.9% "Well", 10.9% "A little", 20.0% "Very little", and 56.4% "Not at all".

To the question, "How well do you know how astrometric and photometric observations are conducted?", the students in the experimental group answered as follows: 1.8% "Very well", 7.3% "Well", 16.4% "A little", 27.3% "Very little", and 47.3% "Not at all". In the control group, the students' responses were as follows: 3.6% "Very well", and 10.9% "Well", 5.5% "A little", 21.8% "Very little", and 58.2% "Not at all".

To the question, "Can you conduct astrometric and photometric observations?", the students in the experimental group answered as follows: 1.8% "To a very great extent", 9.1% "To a great extent", 21.8% "To a small extent", and 67.3% "Not at all". In the control group, the students' responses were as follows: 1.8% "To a very great extent", 10.9% "To a great extent", 16.4% "To a small extent", and 70.9% "Not at all".

To the question, "Have you previously used software for obtaining and analysing astrometric and photometric data?", the students in the experimental group answered as follows: 1.8% "To a very great extent", 16.4% "To a great extent", 27.3% "To a small extent", and 54.5% "Not at all". In the control group, the students' responses were as follows: 1.8% "To a very great extent", 14.5% "To a great extent", 30.9% "To a small extent", and 52.7% "Not at all".

To the question, "To what extent do you have the skills to use the necessary tools (telescope and camera) for conducting astrometric and photometric observations?", the students in the experimental group answered as follows: 1.8% "To a very great extent", 5.5% "To a great extent", 16.4% "To a small extent", and 76.4% "Not at all". In the control group, the students' responses were as follows: 3.6% "To a very great extent", 5.5% "To a great extent", 16.4% "To a small extent", and 74.5% "Not at all".

To the question, "To what extent do you show interest and curiosity in conducting astrometric and photometric observations?", the students in the experimental group answered as follows: 67.3% "To a very great extent", 30.9% "To a great extent", 0.0% "To a small extent", and 1.8% "Not at all". In the control group, the students' responses were as follows: 65.5% "To a very great extent", 34.5% "To a great extent", 0.0% "To a small extent", and 0.0% "Not at all".

To the question, "How necessary are astrometric and photometric observations for learning astronomy?", the students in the experimental group answered as follows: 70.9% "Very necessary", 29.1% "Necessary", and 0.0% "A little necessary". In the control group, the students' responses were as follows: 65.5% "Very necessary", 34.5% "Necessary", and 0.0% "A little necessary".

Objectives of the pedagogical training experiment were as follows: Analysing and interpreting the initial level of investigative competence in gifted students based on the data from the assessment pedagogical experiment; Developing an appropriate pedagogical model for forming investigative competence in gifted students through extracurricular astronomy activities; Experimental implementation of the developed model by applying an appropriate methodology for forming investigative competence.

Research Methodology. The pedagogical training experiment included the following stages:

- Examining the responses obtained from the assessment questionnaire to analyse and interpret the data;
- Analysing the existing specialised literature on developing investigative competence in students to identify the most relevant and up-to-date pedagogical information and practices for designing a suitable pedagogical model for forming investigative competence in gifted students through extracurricular astronomy activities;
- Organising and conducting the investigative competence training programme for gifted students through extracurricular astronomy activities.

With the gifted students from the experimental group, a series of theoretical and practical observational astronomy activities were conducted online at the Astronomical Observatory of the "Răsvan Angheluță" Natural Sciences Museum Complex in Galați.

The theoretical activities of the observational astronomy course consisted of 13 modules, each lasting three hours. The theoretical sessions were conducted online via Google Meet [37]. The performance evaluation of gifted students in theoretical activities was carried out through knowledge assessment tests using Google Forms. In the first knowledge assessment test, approximately 95% of students scored 11 or 12, while a small percentage of about 5% scored lower.

In the second knowledge assessment test, approximately 93% of students scored 11 or 12, while around 7% of the experimental group recorded lower scores.

The practical activities of the observational astronomy course were conducted using Google Meet and AnyDesk Remote Desktop [35] and included the following:

- Practical training in using the telescope and CCD camera for astronomical observations. These activities were scheduled in the evening before sunset, consisting of 25 modules, each lasting three hours.
- Astronomical observations conducted together with the students. These activities took place over 23 nights. The educational objective of the practical training on using the telescope and CCD camera, as well as the astronomical observations, was to develop skills in using software to control the telescope and CCD camera. These practical activities were carried out using the equipment available at the Galați Astronomical Observatory [32, pp. 658-661].
- Data reduction and analysis conducted together with the students. These activities were organised into 20 three-hour modules. The educational objective of these activities was to develop skills in using Astrometrica, AstroImageJ, Peranso, and Vstar for reducing astrometric and photometric data and analysing light curves [28, p. 153].

The performance evaluation of gifted students from the experimental group in practical activities was conducted through two individual astronomical research projects. The first project, "Study of Asteroids Using Astrometrica Software", aimed to assess students' knowledge, skills, and abilities in using Astrometrica for astrometric data reduction. Statistically, approximately 89% of students received ratings of "Very Good" or "Good", suggesting that most students acquired the necessary knowledge and skills. A small proportion (about 11%) who received "Satisfactory" ratings indicated potential gaps in understanding or application [27, p. 113]. The second research project, "Study of Variable Stars Using Photometric Methods", aimed to evaluate students' ability to use the necessary software for reducing photometric data and analysing light curves. About 85% of students received ratings of "Very Good" or "Good", indicating skill development, while approximately 15% received "Satisfactory" ratings, suggesting some deficiencies in applying software for scientific data analysis [28, p. 155]. Together with the gifted students in the control group from Romania, a series of activities were conducted at the Astronomical Observatory within the "Răsvan Angheluță" Natural Sciences Museum Complex in Galați. These activities included 12 online lessons, each lasting 3 hours, conducted through the Google Meet communication application. The lessons covered basic astronomy concepts and familiarise students with essential astronomy principles without delving into complex details.

The objectives of the pedagogical validation experiment were as follows: Developing a questionnaire to evaluate the level of investigative competence development in gifted students at the end of the training program; Experimentally applying the questionnaire to determine the level of investigative competence development in gifted students, to assess the effectiveness of the training program; Evaluating the efficiency of the pedagogical model and the methodology for developing

investigative competence in gifted students through extracurricular astronomy activities, to identify potential needs for adjustments or improvements in future instruction and evaluation.

Research Methodology. The pedagogical validation experiment included the following stages:

- Developing a set of specific questions for the validation questionnaire;
- Distributing the validation questionnaire through a Google Forms platform, using students' email addresses;
- Analysing and interpreting the data collected from the validation questionnaire;
- Comparing, analysing, and interpreting the data collected from the assessment and validation questionnaires. The results obtained in the experimental group were compared with those obtained in the control group.

The following table presents the research methodology for the pedagogical validation experiment (Table 3.4).

Table 3.4. Research methodology for the pedagogical validation experiment

Sample type	Number and categories of subjects	Validation
Experimental Group	Republic of Moldova: 55 students from grades VI - XII	Questionnaire
Control Group	Romania: 55 students from grades VI – XII	Questionnaire

In the pedagogical validation experiment, the questionnaire was used to determine the level of development of investigative competence in gifted students, to assess the effectiveness of the training program. To illustrate the results obtained in the validation stage, items 3 and 5 from the validation questionnaire were selected.

Item 3: How do you assess your level of knowledge regarding the methodology of astrometric and photometric observations? The distribution of responses to Item No. 3 for each research group is presented in Figure 3.5.

Figure 3.5. Distribution of responses to item No. 3 for each research group

Item 5: To what extent do you consider that you have developed skills in using software for reducing and analysing astrometric and photometric data?

The distribution of responses to Item No. 5 for each research group can be viewed in Figure 3.6.

Fig. 3.6. Distribution of responses to item No. 5 for each research group

The following are the results obtained from the application of the validation questionnaire: To the question, "To what extent do you know about the functioning of the telescope and the CCD camera?", the students in the experimental group answered as follows: 83.6% "To a very great extent", 14.5% "To a great extent", 1.8% "To a small extent", 0.0% "Not at all". In the control group, the students' responses were as follows: 0.0% "To a very great extent", 21.8% "To a great extent", 43.6% "To a small extent", 34.5% "Not at all".

To the question, "To what extent are you familiar with using software for reducing and analysing astrometric and photometric data?", the students in the experimental group answered as follows: 72.7% "Very well", 21.8% "Well", 3.6% "A little", 1.8% "Very little", 0.0% "Not at all". In the control group, the students' responses were as follows: 1.8% "Very well", 10.9% "Well", 14.5% "A little", 25.5% "Very little", 47.3% "Not at all".

To the question, "How would you assess your level of knowledge about the methodology of astrometric and photometric observations?", the students in the experimental group answered as follows: 81.8% "Very well", 10.9% "Well", 7.3% "A little", 0.0% "Very little", 0.0% "Not at all". In the control group, the students' responses were as follows: 3.6% "Very well", 12.7% "Well", 7.3% "A little", 23.6% "Very little", 52.7% "Not at all".

To the question, "To what extent do you consider yourself capable of performing astrometric and photometric observations?", the students in the experimental group answered as follows: 67.3% "To a very great extent", 23.6% "To a great extent", 9.1% "To a small extent", 0.0% "Not at all". In the control group, the students' responses were as follows: 1.8% "To a very great extent", 10.9% "To a great extent", 20.0% "To a small extent", 67.3% "Not at all".

To the question, "To what extent do you consider you have developed skills to use software for reducing and analysing astrometric and photometric data?", the students in the experimental group answered as follows: 76.4% "To a very great extent", 20.0% "To a great extent", 3.6% "To a small extent", 0.0% "Not at all". In the control group,

the students' responses were as follows: 3.6% "To a very great extent", 16.4% "To a great extent", 30.9% "To a small extent", 49.1% "Not at all".

To the question, "Do you have the skills to perform astrometric and photometric observations using the necessary instruments (telescope and camera)?", the students in the experimental group answered as follows: 72.7% "To a very great extent", 16.4% "To a great extent", 10.9% "To a small extent", 0.0% "Not at all". In the control group, the students' responses were as follows: 5.5% "To a very great extent", 5.5% "To a great extent", 18.2% "To a small extent", 70.9% "Not at all".

To the question, "To what extent are you interested and curious to learn through investigation how to make astrometric and photometric observations?", the students in the experimental group answered as follows: 87.3% "To a very great extent", 12.7% "To a great extent", 0.0% "To a small extent", 0.0% "Not at all". In the control group, the students' responses were as follows: 67.3% "To a very great extent", 32.7% "To a great extent", 0.0% "To a small extent", 0.0% "Not at all".

To the question, "In the process of learning astronomy, how necessary are astrometric and photometric observations?", the students in the experimental group answered as follows: 90.9% "Very necessary", 9.1% "Necessary", 0.0% "A little necessary". In the control group, the students' responses were as follows: 65.5% "Very necessary", 34.5% "Necessary", 0.0% "A little necessary".

For the statistical analysis of the results obtained in the pedagogical experiment, the Statistical Package for the Social Sciences (SPSS) software was used [16]. The following section presents the statistical analysis of the data obtained from the assessment and validation experiments to identify trends in the studied variables. For this purpose, the Chi-square test (χ^2), was used to evaluate the validity and consistency of the results. The statistical analysis results for the assessment experiment, including the studied variables and the corresponding p-values obtained from the application of the Chi-square test (χ^2), are presented in Table 3.1.

Table 3.1. Statistical results for the studied variables in the pedagogical assessment experiment

Research variable	p-value	Conclusions
Knowledge of instruments (telescope and camera)	0.686	There are no significant differences between the experimental and control groups
Knowledge of software use for reduction and analysis of astrometric and photometric data	0.839	There are no significant differences between the experimental and control groups
Knowledge of astrometric and photometric observation methodology	0.321	There are no significant differences between the experimental and control groups

Ability to perform astrometric and photometric observations	0.572	There are no significant differences between the experimental and control groups
Skills and proficiency in using software for reduction and analysis of astrometric and photometric data	0.977	There are no significant differences between the experimental and control groups
Proficiency in using instruments (telescope and camera) to perform astrometric and photometric observations	0.951	There are no significant differences between the experimental and control groups
Interest and curiosity in learning through investigation in conducting astrometric and photometric observations	0.570	There are no significant differences between the experimental and control groups
Awareness of the importance of learning astronomy through astrometric and photometric observations	0.539	There are no significant differences between the experimental and control groups

In conclusion, the results of the Chi-square test (χ^2) used to analyse the data obtained in the pedagogical assessment experiment demonstrate that there is an insignificant interdependence between the distribution of the studied variables and the research group (the levels of the studied variables do not significantly depend on the research sample).

This indicates that the experimental and control groups were statistically similar (homogeneous) before the start of the pedagogical training experiment.

The statistical results obtained for the validation experiment are presented in Table 3.2.

Table 3.2. Statistical Results for the Studied Variables in the Pedagogical Validation Experiment

Research variable	p-value	Conclusions
Knowledge of instruments (telescope and camera)	< 0.001	There are significant differences between the experimental and control groups

Knowledge of software use for reduction and analysis of astrometric and photometric data	< 0.001	There are significant differences between the experimental and control groups
Knowledge of astrometric and photometric observation methodology	< 0.001	There are significant differences between the experimental and control groups
Ability to perform astrometric and photometric observations	< 0.001	There are significant differences between the experimental and control groups
Skills and proficiency in using software for reduction and analysis of astrometric and photometric data	< 0.001	There are significant differences between the experimental and control groups
Proficiency in using instruments (telescope and camera) to perform astrometric and photometric observations	< 0.001	There are significant differences between the experimental and control groups
Interest and curiosity in learning through investigation in conducting astrometric and photometric observations	0.012	There are significant differences between the experimental and control groups
Awareness of the importance of learning astronomy through astrometric and photometric observations	0.001	There are significant differences between the experimental and control groups

P-values displayed as 0.000 by SPSS are presented in the table above as $p < 0.001$ for clarity, as the exact probability is lower than the software's display threshold. In conclusion, the results of the Chi-square test (χ^2) used to analyse the data obtained in the validation experiment demonstrate that there is a significant interdependence between the distribution of the studied variables and the research group (the levels of the studied variables significantly depend on the research sample).

In other words, the pedagogical intervention tested in the validation experiment had a statistically significant effect on the measured variables, and the differences observed

between the two groups (experimental and control) are not due to chance but indicate that the pedagogical model and methodology for developing investigative competence in gifted students through extracurricular astronomy activities had a significant impact, thus validating their effectiveness in the studied context.

GENERAL CONCLUSIONS AND RECOMMENDATIONS

The studies and research conducted, both from a theoretical and practical perspective, facilitated the understanding and presentation of the theoretical and methodological foundations that formed the basis for creating the pedagogical model and methodology for developing investigative competence in gifted students through extracurricular astronomy activities.

The theoretical and experimental findings obtained validated the research hypothesis and met the established objectives, allowing for the following conclusions to be drawn:

- To address the specific needs of gifted students, the Pedagogical Model for Developing Investigative Competence in Gifted Students through Extracurricular Astronomy Activities was developed. This model provides a theoretical and applied framework tailored to the understanding and interests of these students.
- The development of a pedagogical model for cultivating investigative competence in gifted students through extracurricular astronomy activities facilitated the design of an effective methodology for developing this competence. The proposed methodology contributed to both the accumulation of astronomy knowledge and the enhancement of the capacities, skills, and abilities of gifted students in observational astronomy, ultimately leading to the formation of investigative competence.
- The results of statistical analysis, along with knowledge evaluation tests and astronomical research projects, demonstrate that the pedagogical model and methodology applied in the pedagogical experiment had a significant impact on the gifted students in the experimental group. This confirms the initial research hypothesis that extracurricular astronomy activities contribute to the development of investigative competence in gifted students.
- The research objectives were achieved, leading to the resolution of the research question: What is the methodology for developing investigative competence in gifted students through extracurricular astronomy activities? The resolution of the research problem and the fulfilment of the proposed objectives are confirmed by the results published in articles ([24], [25], [26], [27], [28], [29], [30], [32]) and contribute to expanding the existing knowledge base in the field of developing investigative competence in gifted students through extracurricular astronomy activities, providing new perspectives and insights.
- Extracurricular astronomy activities motivated students to adopt the role of researchers, stimulating their initiative and autonomy.

- Through these activities, students had the opportunity to develop observation, analysis, critical thinking, and problem-solving skills, all essential for their future roles as researchers.
- Mentorship played a crucial role in guiding students through the complexity of the investigative process, facilitating a deeper understanding of astronomical concepts.

Considering the conclusions discussed earlier, the following recommendations are proposed:

- ✓ For the Educational System:
  - Develop and implement similar extracurricular activity programs in other scientific fields to foster investigative competence in gifted students.
  - Integrate astronomical observations into the school curriculum to ensure all students have access to inquiry-based learning opportunities.
  - Train teachers in organizing extracurricular astronomy activities, applying the methodology for developing investigative competence presented in this thesis.
- ✓ For Research in the Field of Educational Sciences:
  - Conduct in-depth studies to evaluate the impact of integrating astronomical observations into the school curriculum on students' development of investigative competence.
- ✓ For Education Policies:
  - Support the development of the necessary infrastructure, such as astronomical observatories and planetariums, to facilitate extracurricular astronomy activities. This objective can be achieved through the initiation of projects funded by European funds.
  - Allocate resources and funds, both governmental and European, to support programs that promote education in STEM fields (Science, Technology, Engineering, and Mathematics).
  - Encourage and support partnerships between schools and planetariums/astronomical observatories to provide students with access to specialized resources and the expertise of professionals in the field of astronomy.

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ADNOTARE

Tercu Jan-Ovidiu, Formarea competenței investigaționale a elevilor dotați prin intermediul activităților extrașcolare de astronomie. Teză de doctor în științe ale educației, Chișinău, 2025

Structura tezei: Introducere, trei capitole, concluzii generale și recomandări, bibliografia din 239 de titluri, 154 pagini de text de bază, 46 figuri, 5 tabele, 34 anexe. Rezultatele obținute sunt publicate în 9 lucrări științifice.

Cuvinte-cheie: competență investigațională, elevi dotați, activități extrașcolare, astronomie, model pedagogic de formare a competenței investigaționale, metodologia formării competenței investigaționale.

Scopul cercetării: constă în fundamentarea teoretică şi praxiologică a competenței investigaționale, elaborarea și validarea experimentală a modelului pedagogic de formare a competenţei investigaționale a elevilor dotați în cadrul activităților extrașcolare de astronomie.

Obiectivele cercetării: 1) Analiza conceptelor fundamentale teoretice referitoare la modul de definire și necesitatea formării competenței investigaționale a elevilor dotaţi în cadrul activităților extrașcolare de astronomie. 2) Determinarea fundamentelor metodologice pentru formarea competenței investigaționale a elevilor dotați. 3) Elaborarea și validarea experimentală a modelului pedagogic de formare a competenței investigaționale la elevii dotați în cadrul activităților extrașcolare de astronomie.

Noutatea şi originalitatea ştiinţifică a cercetării: constă în elaborarea metodologiei și a modelului pedagogic pentru formarea competenței investigaționale a elevilor dotați prin intermediul activităților extrașcolare de astronomie.

Rezultatele obținute care contribuie la soluționarea unei probleme științifice importante: a fost elaborată Metodologia formării competenței investigaționale a elevilor dotați în cadrul activităților extrașcolare de astronomie, care permite elevilor să investigheze noțiuni de astronomie dincolo de curriculumul standard, acest lucru stimulând curiozitatea și interesul acestora pentru știință.

Semnificația teoretică a cercetării: constă în contribuția adusă la dezvoltarea înțelegerii asupra procesului de formare a competenței investigaționale în cadrul activităților extrașcolare de astronomie, precum și la extinderea cunoștințelor existente în domeniul pedagogiei.

Valoarea aplicativă a cercetării: constă în furnizarea unei metodologii și a unui model pedagogic, care pot fi utilizate în practica educațională pentru a dezvolta competența investigațională a elevilor dotați prin intermediul activităților extrașcolare de astronomie. Această cercetare oferă resurse practice pentru profesorii de fizică și specialiștii în domeniul educației în astronomie care doresc să îmbunătățească procesul de învățare în domeniul astronomiei.

Implementarea rezultatelor ştiinţifice: s-a concretizat prin validarea experimentală a metodologiei și a modelului pedagogic de formare a competenței investigaționale a elevilor dotați în cadrul activităților extrașcolare de astronomie, desfășurate la Observatorul Astronomic al Complexului Muzeal de Științele Naturii "Răsvan Angheluță" Galați, România. De asemenea, metodologia și modelul pedagogic dezvoltate au fost integrate în activitățile extrașcolare organizate la Observatorul Astronomic al Universității Tehnice a Moldovei din Chișinău, Republica Moldova.

АННОТАЦИЯ

Терку Жан-Овидиу, Формирование исследовательской компетентности одаренных учащихся посредством внеклассных занятий по астрономии. Докторская диссертация в области педагогических наук, Кишинев, 2025 г.

Структура диссертации: Введение, три главы, общие выводы и рекомендации, библиография из 239 наименований, 154 страниц основного текста, 46 рисунков, 5 таблиц, 34 приложений. Полученные результаты опубликованы в 9 научных статьях.

Ключевые слова: исследовательская компетентность, одаренные учащиеся, внеклассная деятельность, астрономия, педагогическая модель формирования исследовательской компетентности, методика формирования исследовательской компетентности.

Цель исследования: Теоретическое и праксиологическое обоснование исследовательской компетентности, разработке и экспериментальном обосновании педагогической модели воспитания исследовательской компетентности одаренных учащихся при внеклассных занятий по астрономии.

Задачи исследования: 1) Анализ фундаментальных теоретических положений, касающихся способа определения и необходимости формирования исследовательской компетентности одаренных учащихся при внеклассных занятий по астрономии. 2) Определение методических основ формирования исследовательской компетентности одаренных учащихся. 3) Разработка и экспериментальное обоснование педагогической модели формирования исследовательской компетентности одаренных учащихся в рамках внеклассных занятий по астрономии.

Новизна и научная оригинальность исследования заключается в разработке методики и педагогической модели формирования исследовательской компетентности одаренных учащихся посредством внеклассных занятий по астрономии.

Полученные результаты способствуют решению важной научной проблемы:
Разработана Методика развития исследовательской компетентности одаренных учащихся при внеклассных занятий по астрономии, которая позволяет учащимся исследовать концепции астрономии за пределами стандартной учебной программы, стимулируя тем самым их любознательность и интерес к науке.

Теоретическая значимость исследования заключается во вкладе, внесенном в развитие понимания процесса формирования исследовательской компетентности при внеклассных занятий по астрономии, а также в расширение имеющихся знаний в области педагогики.

Прикладная ценность исследования заключается в предоставлении методологии и педагогической модели, которые могут быть использованы в образовательной практике для развития исследовательской компетентности одарённых учащихся при внеклассных занятий по астрономии. Это исследование предоставляет практические ресурсы для учителей физики и преподавателей астрономии, которые хотят улучшить обучение астрономии.

Внедрение научных результатов реализовано посредством экспериментальной проверки методики и педагогической модели формирования исследовательской компетентности одаренных учащихся при внеклассных занятий по астрономии, проведенной в Астрономической обсерватории Музейного Комплекса Естественных Наук «Рэзван Ангелуцэ». Галац. Также разработанная методология и педагогическая модель были интегрированы во внеклассные мероприятия, организованные в Астрономической обсерватории Технического университета Молдовы в Кишиневе, Республика Молдова.

ANNOTATION

Tercu Jan-Ovidiu, Formation of the investigative competence of gifted students through extracurricular astronomy activities. PhD Thesis in Educational Sciences, Chișinău, 2025

Structure of the thesis: introduction, three chapters, recommendations and conclusions referring to the whole thesis, bibliography listing 239 titles, 154 pages of basic text, 46 figures, 5 tables, 34 annexes. The obtained results are published in 9 scientific papers.

Keywords: investigative competence, gifted students, extracurricular activities, astronomy, pedagogical model of developing the investigative competence, methodology of investigative competence formation.

Research Aim: consists in both, the theoretical and praxiological argumentation of the investigative competence, in the elaboration and in the validation through experiments of the pedagogical model for achieving the investigative competence in the case of the gifted students implied in extracurricular astronomy activities.

The Objectives of the Research: 1) To analyse the fundamental theoretical concepts regarding the definition and need to train the investigative competence of gifted students during extracurricular astronomy activities; 2) To determine the methodological foundations for the formation of the investigative competence of gifted students; 3) To elaborate and to validate through experiments the pedagogical model for achieving the investigative competence in the case of the gifted students implied in extracurricular astronomy activities.

The scientific novelty and originality of the research: consist not only, in the elaboration of the methodology, but also in presenting the pedagogical model for the formation of the investigative competence of gifted students through extracurricular astronomy activities.

The Obtained Results that Contribute to solve an Important Scientific Issue: The methodology of formation of the investigative competence of gifted students was developed within and in the framework of the extracurricular astronomy activities. This fact allows students to investigate notions of astronomy beyond the standard curriculum level and stimulates their curiosity and interest in studying sciences.

The theoretical significance of the research: The theoretical significance of the research resides, first, in the contribution brought to the development of the understanding of the process of formation of the investigative competence within the extracurricular astronomy activities, as well as to the extension of the existing knowledge in the field of pedagogy.

The applicative value of the research: This aspect consists of providing a methodology and a pedagogical model, which can be used in educational practice to develop the investigative competence of gifted students through extracurricular astronomy activities. This research provides practical resources for physics teachers and astronomy education specialists who want to improve the learning process in astronomy.

The Implementation of the scientific results: it was materialized through the experimental validation of the methodology and of the pedagogical model for the formation of the investigative competence of the gifted students within the extracurricular astronomy activities, carried out at the Astronomical Observatory of the "Răsvan Angheluță" Natural Sciences Museum Complex from Galați, Romania. Also, the developed methodology and pedagogical model were integrated into the extracurricular astronomy activities organized at the Astronomical Observatory of the Technical University of Moldova from Chișinău, Republic of Moldova.

TERCU Jan-Ovidiu

DEVELOPING INVESTIGATIVE COMPETENCE IN GIFTED STUDENTS THROUGH EXTRACURRICULAR ASTRONOMY ACTIVITIES

Speciality 532.02 – School Didactics by Levels and Educational Disciplines

SUMMARY
of the doctoral thesis in educational sciences
Chișinău, 2025

Approved for printing: 4 February 2025 Paper format: 60 x 84 1/16

Offset paper. Offset printing Print run: 20 copies.

Printing sheets: 2.0

UPSC Typography, 1 I. Creangă Street,
Chișinău, MD-2069