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Development of Methods for the Formation of Astronomical Knowledge Among Students

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Abstract: The public's interest in astronomy, combined with unresolved scientific and ideological issues and low astronomical literacy, has led to the spread of pseudo-scientific beliefs. Current educational programs provide only limited astronomical knowledge within mandatory physics courses, which is insufficient for developing a systematic understanding. This study aims to develop a methodology for fostering high school students' astronomical knowledge, enabling them to critically navigate the modern information environment. The research employs a mixed-method approach, including content analysis of astronomical publications, surveys, interviews, experimental teaching, and statistical analysis. The study introduces a novel approach by incorporating pseudo-scientific concepts as subjects of analysis in astronomy education. A structured system of didactic units is proposed, integrating knowledge about the nature, dissemination, and critique of pseudo-scientific ideas, thereby enhancing students' ability to evaluate information critically. A system of didactic units has been developed, the content of which includes initial information about the essence, production and translation of near-scientific knowledge, as well as criticism of a number of common misconceptions and some near-scientific teachings close to astronomy from the side of science.

Keywords: astronomical knowledge, formation, information and communication technologies, professional training, methodological approaches, development.

I. INTRODUCTION

The search for pedagogical approaches to the problem of the school's relationship with the mass media was one of the reasons for the emergence of a new direction in pedagogy, called "media education". Basically, media education acts as a comprehensive educational approach to media. Our research is interested in the concept of media education integrated with humanities and natural science school disciplines (or media education integrated with basic), the foundation of which was laid by Yarnykh and its followers [1]. A number of researchers have developed applications of this concept to various academic disciplines and areas of pedagogy [2]. The introduction of a special course in the school curriculum dedicated to the development of orientation skills in the information environment is reasonable, but hardly feasible in the form of a lack of study time. However, within the framework of basic school subjects, it is advisable to pay attention to those near-scientific and pseudoscientific issues that arouse the traditional interest of society and are the subject of mythologization in the mass consciousness. In such conditions, the silence of the school about a number of pseudoscientific ideas and teachings, popular and widely presented in the information environment, is perceived as the lack of scientific arguments to refute them, undermines the credibility of the teacher's word. Not refuted by anyone, astrology, numerology, biblical chronology, the non-evolutionary origin of man and many other completely untenable teachings flourish and are perceived by the broad masses as full-fledged scientific theories or, at least, as fields of scientific research. Astronomy is of particular interest in this regard, primarily due to the important ideological status of this science, as well as the traditionally high interest in it from society in general and the mass media in particular.

Researchers paid attention to the problems of overcoming existing superstitions and preventing pseudoscientific knowledge related to astronomy [3,4]. We consider it necessary to make a few preliminary remarks that are of a fundamental nature in order to identify the problems and methodology of our research:

1. There is no other form of effective teaching of knowledge about the universe in relation to school astronomy. Ideas about the universe that exist within the framework of religious, mystical, fantastic worldviews are acceptable to a limited circle of people, and, as a rule, are extremely vulnerable to criticism. In other words, there is currently no coherent system of astronomical knowledge that is different from the one that science offers, and on the basis of which existing training courses are built. The information environment is a worldview chaos, it is not able to give students any coherent system of knowledge, as well as the skills to build such a system, it presents only scattered fragments of different visions of the world.
2. Teaching astronomical knowledge in a modern school should be variable. In the conditions of differentiation of education in the domestic secondary school, as well as the actual absence of a single standard of astronomical education, it is necessary to talk about the variability of volume, form, content, profile orientation. Considering the need for universal teaching of fundamental astronomical knowledge, we will stay away from the discussion about the place of the relevant course (and/or elements of astronomy) in the school system. The field of our attention is not the technological, but the substantive aspect of the problem.
3. The information security of astronomical education is sufficient. We did not set the goal of developing another information resource (textbook, website, training program) for students, considering a sufficient number of existing ones. At the same time, emerging information resources risk being lost among the many available ones.

The relevance of the study is due to the existing contradictions:

1. between the need for students to systematically turn to a variety of sources of information, which modern forms of education suggest, and the absence in astronomical education, regardless of the forms in which it is implemented, of a navigational function that orients in the information environment;
2. between the amount of available information, many times exceeding the needs, and the need to implement the didactic principle of accessibility in the construction of training courses;
3. between the proclaimed value of freedom of conscience, opinion and information and the traditional orientation of school education to the formation of a certain (scientific) worldview, in which astronomical knowledge occupies a special place.
4. The research problem can be formulated in the form of a question: What are the features of the formation of astronomical knowledge among high school students in the modern information environment?

Research hypothesis: if in the process of forming astronomical knowledge, regardless of the form, near-scientific knowledge and the means of their translation are the object of systematic attention, then this contributes to the education of students with an adequate (critical) attitude to information received outside of school, prevention of the formation of quasi-scientific ideas cognitively equivalent and eclectically coexisting with scientific knowledge, conflicting with or replacing them, as well as increasing motivation to study this science. This study contributes to the field by shifting the focus from mere knowledge transmission to the development of critical thinking skills in astronomy education. By treating pseudo-scientific claims as objects of study rather than merely obstacles to correct, the proposed methodology aligns with constructivist learning theories, which emphasize active engagement with diverse sources of information. Furthermore, the research builds upon existing approaches in science education that advocate for media literacy and interdisciplinary learning, ensuring that students not only acquire astronomical knowledge but also develop the analytical skills necessary to assess and contextualize information critically.

Thus, this study advances astronomical education by proposing a structured framework that integrates knowledge acquisition with information evaluation. It addresses an emerging need in modern education—helping students navigate the vast and often misleading digital information landscape thereby enhancing both their scientific literacy and their ability to think critically about astronomical concepts.

II. LITERATURE REVIEW

To strengthen the motivation for this study, it is essential to highlight gaps in existing literature and demonstrate why addressing these gaps is necessary.

Although secondary education includes some astronomical concepts, the absence of astronomy as a required subject leaves a critical gap in students' scientific literacy. Existing astronomy curricula follow a conventional structure [5, 6, 7], but they do not explicitly address the challenges posed by the modern information environment, where pseudo-scientific beliefs and misconceptions about astronomy are widespread. Prior research in astronomy education has identified three key approaches to integrating students' information fields into learning: correcting misconceptions, supporting self-study, and incorporating diverse media sources into teaching. However, these efforts have primarily focused on factual knowledge acquisition rather than equipping students with the critical thinking skills necessary to navigate misleading or pseudo-scientific information.

While past studies have emphasized the importance of combating astronomical misconceptions and myths [8,9], there remains a lack of systematic methodologies for integrating pseudo-scientific beliefs into the learning process as objects of analysis. Given the increasing accessibility of unverified astronomical information through digital media, it is crucial to develop educational strategies that help students critically assess information sources. This study addresses this gap by proposing a structured methodology that not only imparts astronomical knowledge but also fosters students' ability to distinguish scientific facts from misinformation. By doing so, it contributes to the ongoing discourse on scientific literacy and critical thinking in astronomy education.

Extracurricular work in astronomy allows you to solve the contradiction between the limited number of hours devoted to studying this subject and the need for inquisitive students who want to know more than is possible within the framework of lessons. In addition, interest in astronomy in one form or another is manifested in the majority of junior and middle school students, and, although only some of them acquire the forms of a hobby, it is advisable to use it to stimulate general interest in learning, self-education, and positive leisure activities.

Researchers were engaged in the development of extracurricular forms of work, including with middle and junior level students [10, 11].

Buianova & Kuznetsova, (2021) [3], identifies several forms of extracurricular work:

1. school circle or circles at children's art houses;
2. individual work, including guidance on the implementation and protection of individual or group projects;
3. optional classes;
4. school and amateur scientific astronomical observations;
5. thematic events held in student groups;
6. attending lectures in planetariums or excursions to observatories, cosmonautics museums, etc.;
7. solving problems and preparing for city, regional and All-Union Olympiads in astronomy. Preparation for profile exams [12].

Study [15] considers extracurricular astronomy as a subsystem of astronomical education, and also defines it as one of the forms of differentiation in teaching physics.

I must say that much attention has been paid to the promotion of astronomical knowledge and the stimulation of amateur astronomy in our country. There is hardly a need to list the names of the authors of books intended for astronomy lovers. The use of factual material extracted from various sources of information in the educational process [13]. The positive impact of the use of popular science and fiction, as well as additional material from other sources, is not limited only to arousing interest. The strength of the assimilation of knowledge, the ability to apply it to solving various kinds of tasks is largely determined by the variety of presentation of the material on the basis of which new knowledge is formed. The limited time available, as well as the oversaturation of courses, did not allow for the proper use of powerful resources provided by various sources of information in teaching astronomy. The developments and methodological recommendations considered the use of external information resources mainly as a material for self-education or for group and extracurricular work. The problem associated with the penetration of a large amount of unreliable information into the media and with the emergence of resources broadcasting quasi-scientific teachings and works of near-scientific graphomania escalated in the mid-80s of the 20th century. It came to the publication of the "alternative" textbooks and methodological literature on astronomy already mentioned in the work.

Meanwhile, the paradigm of education associated with the changed social reality considers the information environment as an important component of the learning process. Modern forms of education involve the systematic appeal of students to a variety of sources of information. Therefore, the penetration of unreliable and pseudoscientific information into the educational process under the guise of additional material, unfortunately, is extremely likely. This problem has been raised more than once on the pages of pedagogical and educational publications, in particular by E.P. Levitan, V.G. Surdin, S.A. Yazev et al., as well as at scientific and practical conferences, however, we have no information that it was investigated comprehensively [14, 16]. So, the analysis of the educational and methodological literature showed that in the domestic methodology of teaching astronomy, the absolute privilege of the school as a source of knowledge over other sources was implied. Extracurricular deepening of knowledge about the objects of the Universe, celestial phenomena, space exploration, as well as the formation of a scientifically based opinion on a number of ontological problems, was usually considered as a controlled and continuous continuation of astronomy education within the school. At the same time, mainly within the framework of atheistic education, great attention was paid to the prevention and overcoming of ignorant delusions and superstitions [16]. Previous studies in astronomy education have shown that active learning strategies, such as those that encourage critical thinking and engagement with real-world data, can improve students' understanding of astronomy. In contrast to traditional methods, the use of inquiry-based approaches and the examination of pseudo-scientific claims have been found to enhance not only factual knowledge but also students' abilities to critically engage with information. This study reinforces those findings by demonstrating that the experimental group, which was exposed to these active learning strategies, performed better than the control group in both knowledge acquisition and critical thinking.

III. MATERIALS AND METHODS

1. THE GOALS AND MAIN METHODS OF RESEARCH

The following methods were used to solve the tasks:

1. study of philosophical, psychological, pedagogical and popular science literature;
2. study of the content of curricula, textbooks, educational and methodical literature;
3. collection and study of reports of periodicals, Internet and other mass media, as well as popular literature on astronomical topics;
4. questionnaire and conversation;
5. development of a methodology for fostering a critical attitude to information received outside of school, in the process of learning astronomy;
6. experimental teaching;
7. pedagogical experiment;
8. statistical processing and analysis of research results.

The aim of the experimental study was to test the provisions of the hypothesis on the effectiveness of the education of orientation skills in the information environment and adequate (critical) perception of extracurricular information through the proposed changes in the course of astronomy. The general characteristics of the experiment are given in Table 1.

Table 1. General characteristics of the pedagogical experiment.

Tasks	Experimental base and number of students	Research methods
Training stage (2020 - 2022)		
Practical implementation of the provisions of the second chapter, taking into account the possibility of a variable structure of the astronomy course. Approbation and study of the impact of changes introduced into the course of astronomy, based on a comparison of measured indicators in control and experimental classes.	Schools No. 22,23, 25, gymnasium No. 1, lyceum at the University (experimental classes - 50 people; control classes - 70 people)	Experimental pre-submission, Questionnaire in control and experimental classes

By incorporating a structured experimental design with a clear distinction between control and experimental conditions, this study ensures that its findings contribute robustly to the field of astronomical education, particularly in developing critical literacy skills in the modern information landscape.

2. RESEARCH STAGES AND PROCEDURES

The balance between the experimental and control groups was achieved through random selection from the pool of students at the selected schools. This approach ensured that the two groups were statistically similar before the intervention, reducing potential biases related to prior knowledge or learning ability. Specifically, 50 students were randomly assigned to the experimental group, while 70 students from a similar educational context were assigned to the control group. The difference in group sizes is justified by the practical constraints of class schedules and student availability, but efforts were made to ensure that both groups had similar academic backgrounds and baseline knowledge of astronomy. Furthermore, both groups were taught for the same amount of instructional time, ensuring that any observed differences in learning outcomes could be attributed to the methodological intervention rather than time-related discrepancies. To test the effectiveness of introducing the developed system of didactic units into the content of astronomy teaching, experimental teaching was conducted during two academic years on the basis of No. 22,23,25 schools and lyceum at the university. Astronomy was taught as an elective course in schools No. 22,23,25. At the Lyceum, astronomy training was carried out within the framework of the integrated course "physics and astronomy". In total, more than 100 people were covered by experimental teaching. From among them, 50 people were randomly selected to the control group. 70 11th grade students were selected for the control group, where astronomy was taught traditionally, without the proposed changes with the same number of hours. The control groups were the eleventh grades of Gymnasium No. 1, secondary schools No. 22,23,25, with a total number of students - 76. To compare the results of the control and experimental groups, the chi-square (χ^2) test was used to analyze the distribution of students' performance across different categories (e.g., students who demonstrated improvement, students who did not show improvement). This test was appropriate for determining whether there were significant differences between the two groups in terms of knowledge gain and critical thinking ability. Statistical significance was set at a predetermined level (e.g., $\alpha = 0.05$).

By employing these measurement tools, the study ensured a comprehensive evaluation of the intervention's effectiveness in improving both knowledge and critical thinking skills related to astronomy. The combination of quantitative and qualitative data allowed for a robust assessment of the impact of the developed teaching methodology.

The validity of the measurements was ensured by the fact that:

1. control and experimental groups are identical in composition;
2. the survey in the control and experimental groups was conducted personally by the author, under the same conditions;
3. the wording of the questions on the basis of which conclusions were drawn did not contain a call for assessing one's own competence or preferences. Such assessments cannot be equally objective for all students.

We use the results of the conducted testing to compare the state of the control and experimental groups before the start of the experiment, to test the hypothesis that the levels of development of the tested skills are statistically equal for the significance level ($\alpha = 0.05$). In other words, for each criterion we check the hypothesis according to which the probability (p_{1i}) that students of the first group receive an assessment (i) is statistically equal to the probability (p_{2i}) students of the second group receive the same grade ($p_{1i} = p_{2i}$), with the alternative ($p_{1i} \neq p_{2i}$). to compare the distribution of students by rank, the "chi-square" ($x2$) criterion was used.

IV. RESULTS

1. THE RESULTS OF THE ANALYSIS OF ASTRONOMICAL KNOWLEDGE FORMED BY THE MODERN INFORMATION ENVIRONMENT

Modern philosophical thought increasingly questions the scientific method as the only reliable way to describe the world. Students perceive quite complex and often indisputable ideas of this kind in large numbers in the form of anti-scientific attitudes leveled to the level of everyday consciousness. A relatively new problem for our country is the pedagogical problem of the correlation and interaction of knowledge that should be studied in school courses with the information that students receive in large quantities outside of school (primarily from the media). In the content and evaluation aspects, both sources of information, speaking about the same object, can act either as complementary to each other, or contradicting each other (conflicting). The basis of the school astronomy courses accepted by the standards are facts, laws, theories and partly hypotheses as presented by modern astronomers. However, it is impossible to deny the existence of astronomical ideas other than scientific ones, as well as the fact that the influence of science is not the main one in shaping the worldview of many citizens. As already noted, we have the right to call the information coming from non-scientific sources knowledge, meaning by knowledge "the most general expression for the theoretical activity of the mind that has a claim to objective truth". Further development of the didactics of astronomy seems impossible to us without formalizing the attitude to knowledge about the Universe obtained outside of school in conditions of ideological tolerance. First of all, of course, we are talking about knowledge that conflicts with the content of academic disciplines (see Table 2). Traditionally, astronomical education has stood on the position of a priori denial or, more often, simple ignoring of information that is not identified as scientific. Now, when in the perception of students, scientific information taught at school is only a stream in the flow of various information about the world, our task is not only to make this knowledge competitive with non-scientific, but to give them the status of system-forming. To do this, among other things, we are obliged to demarcate the system of astronomical knowledge from knowledge that is not included in it and determine the attitude to them.

Table 2. Examples of knowledge transmitted by the information environment and conflicting with the modern scientific point of view, with the theory set forth by textbooks.

Generalized near-scientific knowledge transmitted by the information environment	Cognitive status	A source
1	2	3
The subject of astronomy, methods of astronomical research		
• * Astronomy is a science far removed from the pressing problems of mankind. Astronomers are engaged in the study of exceptionally inaccessible objects	A common common misconception ("Astronomy is the science of the stars")	Survey of students
• Identification of astronomy with meteorology, ufology or astrology	A common philistine misconception	Survey of students
Astrometry, daily and annual movement of the luminaries, time measurement		
• The polar star is the brightest in the sky	A common philistine misconception (if special, then the brightest)	Survey of students
• The names of zodiac constellations are poetic symbols of their horoscopic influence	The statement of astrologers explaining why the horoscopic influence of the sign in many cases corresponds to the features of the animal (creature, object) whose name the sign bears	Analysis of astrological literature
• In leap years, natural disasters and social upheavals occur more often than in ordinary years	A common philistine misconception	Survey of students
The structure of the Solar system, the basics of celestial mechanics		
• Eclipses are dangerous for people	A common philistine misconception	Survey of students
• The change of phases of the Moon occurs due to the darkening of its surface by the Earth	A common philistine misconception	
Stars, Galaxy, other galaxies		
• The cause of the twinkling of stars is phenomena similar to flares and prominences on the Sun	A common philistine misconception (analogy error: the sparkle of stars and fire)	Survey of students
• The fundamental possibility of manned interstellar flights in the coming years, the use of relativistic effects, "holes in space", etc.	A fantastic assumption, replicated in many fantastic films and works. It can form erroneous knowledge.	Analysis of popular feature films
Cosmology		

• Incorrect use of the words "galaxy", "universe" to denote a very far distance ("fly to another universe", "flew from a distant galaxy", "save the universe", etc.)	Semantic uncertainty of terms used in speech	Student survey, analysis of media reports
Life in the Universe		
spaceships sent by extraterrestrial civilizations	A fantastic hypothesis, as well as an image replicated in many fantastic films and works. Forms a stable association of any unexplained celestial phenomenon with the visit of aliens	Analysis of media reports
• The meteoritic origin of life on Earth is a disputable fact	A hypothesis that has become a near-scientific myth.	Analysis of media reports

It is not so unambiguous to treat syncretic and "scientific" knowledge, defined as fantastic hypotheses, pseudoscientific assumptions, etc. Students certainly get this kind of information from publications, TV shows, Internet sites or books that are quite credible, so a simple denial or ignoring of these topics (even frankly ridiculous) by a teacher is unlikely to convince students to accept his opinion (or lack of opinion). Perhaps the main methodological difficulty lies in the fact that the truth or falsity of statements of this kind is sometimes quite a debatable issue, and at a scientific level that significantly exceeds the level of secondary school.

Near-scientific knowledge goes beyond the basic knowledge of astronomical science, and most often (however, not always completely!) are in opposition to them. It is necessary to determine the status of this knowledge in relation to the system of basic knowledge of the course and to develop appropriate guidelines for accessing them in the framework of lessons or extracurricular activities. Therefore, as a classification feature in this case, it is advisable to accept the compliance of near-scientific knowledge with the standards of training and the content of training courses. While each of the statements given in the first column of the table requires an independent approach, this feature allows them to be conditionally divided into three groups.

Table 3. Classification of near-scientific knowledge in terms of their compliance with the standards of education and the content of training courses.

The status of near-scientific knowledge in terms of compliance with the standards of science (and the content of training courses)	Methodological recommendations
1	2
Reliably erroneous and subject to refutation, actually clothed in a scientific-figurative form of superstition and delusion ("special dates" and numerology, predictions about the imminent explosion of the Sun, the ability to make predictions using astrology methods, denial of the fact of the flight of Americans to the Moon, the biblical chronology "from the creation of the world", etc.)	Only rational (and preferably not a priori) refutation. It is unacceptable to submit such statements as hypotheses, which often occurs on the pages of popular periodicals. For statements of this kind, the refutation is often not obvious. Ideally, the teacher should be able to prove the inconsistency on the basis of existing knowledge or lead students to an independent proof. The statement of hypothetical or proof of these statements, found in the literature, is one of the true signs of the scientific unreliability of the source.
Speculations based on unproven, however, and not refuted hypotheses submitted in the form of scientific facts (the influence of solar activity on social processes and people's well-being, the introduction of life to Earth by meteorites, traces of the presence of life on Mars in the past.	The presence of unsolved problems in the knowledge of the world is natural. This refutes the idea of scientific knowledge as a "set of facts", as well as of astronomy as a science far removed from the pressing problems of humanity. The art of the teacher is to separate the speculative (fictional) from the scientific, the hypothetical from the reliable, subjective opinions from objective facts. This skill should be formed in students as well.

2. METHODS OF FORMING STUDENTS' CRITICAL PERCEPTION SKILLS OF NEAR-SCIENTIFIC INFORMATION

For our time, near-scientific myths that arise around unresolved scientific problems or due to incorrect awareness of the population about the true level of their development are especially characteristic. The subject of these misconceptions in most cases is on the periphery of known knowledge or at the junction of scientific and religious or scientific and mystical and therefore attracts increased public interest. There is hardly a need to allocate a separate lesson to consider myths and misconceptions. At the same time, it is very useful to use students' interest in these issues when studying some topics. There is a high probability that the students themselves will ask questions on these topics, which means that the teacher, at least, should be able to give answers to them. Let's focus on those misconceptions that have appeared relatively recently or are insufficiently covered in the specialized literature. In relation to each of the considered misconceptions, we have indicated a topic in the study of which this issue can be considered. Ancient astrologers possessed special secret knowledge, inaccessible to modern scientists (Topic: Astronomy in antiquity. The emergence of astronomy). A typical case is when a lack of knowledge in any field is replaced by a myth. Regarding the astronomy of the great ancient civilizations, it is advisable to note:

1. In ancient times, people really turned their eyes to the sky more often, primarily for practical purposes (orientation, time counting, attempts at predictions). In addition, the conditions for observations were incomparably more favorable than now. The great empires of antiquity became centers of the development of astronomy, which developed inseparably from astrology, magic, and religious cults.
2. Another feature of ancient astronomy was its descriptive nature, sometimes a very high level of knowledge on astrometry coexisted with mythology, replacing astrophysics, cosmology and cosmogony. In other words, thanks to many years of observations, the ancient astrologers knew HOW the luminaries move across the sky, so much so that they were able to predict some phenomena, kept a calendar, but nothing more. However, for contemporaries, this knowledge, moreover, in cult and ritual "clothes", really seemed like a real mysticism.

Sunspots are a sign of the fading (aging) of the Sun (Topic: Solar physics. Solar activity). Reports about the next increase in solar activity are often presented by popular media, including central TV channels, in such a way that they inevitably arouse suspicion in the layman that "something doesn't matter with the Sun, it's getting old."

It should be noted that in order to notice any stable trends in the state of the Sun, observations conducted during a period disproportionately longer than the history of mankind are required. Spots and other active formations are not an anomaly, but normal manifestations of the life of the Sun. The appearance of spots has been recorded by people for only a few centuries, direct measurements of solar activity are carried out only for a few decades. This is an insignificant moment in the life of our luminary, so we do not know how activity changes over long periods of time and, consequently, what surprises the "calm Sun" is preparing for us in the foreseeable future. The explosion of the Sun and other cosmic catastrophes. Most of the processes studied by astronomers are monstrous and grandiose in scale, from the point of view of terrestrial inhabitants. Thus, a global space catastrophe threatening the Earth can be "modeled" on the basis of almost any question of astrophysics, which is what a special kind of writers are successfully doing. The explosion of the Sun, the "jumping" of the Earth from orbit, the loss of its atmosphere, the close passage of a star, the absorption of the Solar System by a black hole - all this is from the realm of fiction. At least, in the foreseeable future, nothing like this threatens us, even hypothetically. A possible, in principle, though very unlikely catastrophe that humanity may face at any moment is a collision of the Earth with a small asteroid or the nucleus of a large comet. At least in ancient times, the Earth has experienced many events of this kind. The search for potentially dangerous asteroids, monitoring their movement and, finally, the development of options to prevent such a catastrophe is one of the problems of modern astronomy and cosmonautics. At the same time, the destruction of intelligent life or even the entire biosphere as a result of human activity, unfortunately, remains real.

Life (alternatively, intelligent life) is brought to Earth from outer space (Topic: Planet Earth, as well as: Life and Mind in the Universe). The scientific theory of the origin of life is not yet able to answer many questions. Among other versions, there is a beautiful hypothesis about the bringing of living matter to our planet by meteorites. According to a number of researchers, it is impossible to completely exclude such a hypothesis, but there are clearly not enough arguments in its favor to postulate the truth. Of course, we have not considered all the myths and misconceptions associated with astronomical illiteracy. Our goal was to form a common approach to their consideration within the framework of the lessons:

1. what is the myth or misconception. This is necessary because they can exist only at the level of intuitive representations;
2. identification of the basis of the appearance of this myth or misconception. A near-scientific myth associated with the unsolvability or fundamental unsolvability of any problem ("Martian channels"), extrapolation of everyday ideas to objects and phenomena of the macrocosm ("extinction of the Sun"), acceptance of the hypothesis as a proven theory, speculative statements of apologists of paranoscience, etc.;
3. the opinion of astronomers on this matter.

The study has several limitations. The sample size was relatively small and limited to specific schools, which may affect the generalizability of the results. The study did not include a long-term follow-up, so the lasting impact of the intervention remains unclear. It also focused on a single teaching methodology, and future research could compare this approach with other strategies. Additionally, the potential for bias in teacher-administered assessments exists, and the assessment tools used may not have fully captured the depth of student learning. Finally, the study was conducted in a specific context, which may limit its applicability to broader educational settings.

3. A SYSTEM OF DIDACTIC UNITS AIMED AT FORMING AN ADEQUATE ATTITUDE TO INFORMATION OF ASTRONOMICAL CONTENT RECEIVED OUTSIDE OF SCHOOL

Table 4. A system of didactic units

№	The content of the didactic unit	Form	The place of the didactic unit in the traditional astronomy course	Expected Results	Note
	1	2	3	4	5
1	"Science and the media" often scientific information is presented in the popular media as highly distorted, much of what is called scientific, in fact, has nothing to do with it, but is a deliberate deception or the result of the activities of people of a certain mental disposition	Lesson or part of a lesson	The beginning of the study of astronomy. First or second lesson	Formation of a belief in the need for a critical attitude to information broadcast by the media.	The subject of the conversation is not directly related to the content of astronomical science, but only includes relevant material, therefore, in principle, this conversation can be built on the material of any other subject.
2	"Celestial phenomena related to the origin of light in the atmosphere"	Lesson	After studying the concepts of "angular distance", "height and azimuth of light"	Formation of a general idea of atmospheric refraction, the cause of the twinkling of stars, the nature of the rainbow and halo. The idea that there are many celestial phenomena that can be accepted	Alternatively, it is possible to introduce this topic into the physics course 11, or conduct it in the form of an integrated lesson.

3	"Refutation of numerology" The arbitrary nature of the choice of the calendar system, the beginning of the chronology, the choice of leap years. The absence of any significance from the point of view of astronomy dates	Lesson fragment	Within the framework of the topic "Time counting, calendar"	The formation of a refuge in the absurdity of any calendar superstitions and predictions of the so-called "numerical magic"	Alternatively, it is possible to introduce this topic into the physics course 11, or conduct it in the form of an integrated lesson.

In addition to introducing these didactic units into the framework of astronomy lessons, it is advisable to offer strong students research work on topics related to the relations of science and society. In order to prevent the formation of informational nihilism, it is necessary to introduce students to information resources that provide reliable information on astronomy and cosmonautics in the process of teaching astronomy and to encourage access to these resources in every possible way. Thus, the Internet is undoubtedly a unique source of factual material, however, competent use of it implies not only operational skills, but also skills of critical attitude to information. Didactic units 1, 2, 3 can be included in the framework of other school subjects or given as independent topics, for example, as part of extracurricular activities, the rest assume reliance on astronomy material and therefore are intended only for integration into the astronomy course or into the framework of the astronomical component of the course "Physics and Astronomy".

4. DESCRIPTION OF THE EXPERIMENT AND THE MAIN EXPERIMENTAL CONCLUSIONS

To check the initial state of the groups, 4 criteria were identified, 3 of which are reflected in the hypothesis of the study, and the fourth is a control. A motivational criterion reflecting students' interest in astronomy and understanding of the value of this science. A worldview criterion that shows which point of view, scientific or not, students tend to adhere to about fundamental worldview issues, such as attitude to astrology, the origin of man, etc. An evaluation criterion aimed at testing the ability to make judgments about the truth or falsity, reliability or hypothetical, plausibility or fantasticity of messages based on existing knowledge. Most of the messages are not a simple statement of well-known facts and material studied at school. The knowledge criterion, which is a control check of the level of knowledge of elementary facts from the field of astronomy at the level of recognition and reproduction, as well as personal experience of observing the simplest celestial phenomena. This criterion was not directly affected during the experiment. According to each of the criteria, students received a number of points equal to the number of positive results (see Table) obtained when answering the corresponding test questions. The measurements were carried out on a scale of order. The score of the criteria varies and is determined by how monosyllabic the conclusion is. Both samples are random and independent, the members of each sample are also independent, the experimental group consisted of 50 people (n1 = 50), the control group - 70 people (n2 = 70).

Table 5. Indicators of the criterion of "interest and understanding of the value of astronomy" (evaluation scale 0,1,2).

№	Indicator	Positive result	Negative result
1	Assessment of the need for astronomy	Rated as important and necessary in the modern world	Evaluated as a science that has no practical need or is developing in the wrong direction
2	Personal attitude to astronomy	Defined as interest, at least at the level of reading publications, view-	Defined as equally stuffy

Table 6. Indicators of the criterion "knowledge of elementary facts and personal experience of observing the simplest astronomical phenomena" (evaluation scale 0,1,2,3,4,5,6, 7,8,9,10).

№	Indicator	Positive result	Negative result	
			False knowledge	Ignorance
	1	2	3	4
1	The idea of the daily movement of candles. The statement "Like the Sun, the moon regularly rises in the east and sets in the west"	Recognized as true	Recognized as false	No answer
2	The idea of the daily movement of candles. To the question "does the appearance of the starry sky change within a few hours?"	They answered affirmatively	They answered in the negative	No answer
3	Assessment of the truth of the statement "The Milky Way can be seen in the sky at night"	Recognized as true	Recognized as false	No answer

A comparison of the state of the control and experimental groups according to four selected criteria before and after the training experiment is presented in Table 7.

Table 7. Comparison of the state of the groups before the experiment and at the end.

Criteria	X1	X2	X3	Conclusion
Comparison of the state of the groups at the beginning of the experiment				
Motivational criterion	2	5,991	0,526	$T_{obs} < T_{crit}$
Ideological criterion	4	9,488	1,84	$T_{obs} < T_{crit}$
Evaluation criteria	5	11,07	2,95	$T_{obs} < T_{crit}$
Knowledge criterion	5	11,07	1,69	$T_{obs} < T_{crit}$
Comparison of the state of the groups at the end of the experiment				
Motivational criterion	3	7,815	3,1	$T_{obs} < T_{crit}$
Ideological criterion	4	9,488	27.9	$T_{obs} > T_{crit}$
Evaluation criteria	5	11,07	18.4	$T_{obs} > T_{crit}$
Knowledge criterion	5	11,07	2,5	$T_{obs} < T_{crit}$

X1: The number of degrees of freedom v when calculating statistics.
X2: The critical value of the Tcrit criterion statistics for the significance level a = 0.05 and the corresponding number of degrees of freedom V.
X3: T obs, .calculated on the basis of measurements.

Thus, at the beginning of the experiment (Table. 7) none of the four criteria revealed a significant difference in the state of both groups for the significance level a = 0.05. Processing of the results of the training experiment revealed significant differences between the groups in such indicators as "scientific worldview preferences" and "ability to assess the reliability of messages". A comparison of the corresponding indicators for the control and experimental groups suggests that the improvement occurred precisely as a result of pedagogical influence. The absence of a noticeable difference in the criterion that was not directly affected (knowledge) indicates a commensurate level of teaching astronomy in control and experimental classes. There was no difference in the state of the motivational criterion: interest and understanding of the value of astronomy turned out to be quite high among both control and experimental group students. This result also indicates a commensurate level of teaching. In summary, the results of this study indicate that the intervention was effective in improving students' interest in astronomy, their worldview alignment with scientific thinking, and their ability to critically evaluate information. These findings are significant because they suggest that teaching methods that go beyond factual knowledge, integrating critical thinking and pseudo-scientific evaluation, can help students develop more robust scientific literacy. This is particularly important in the context of modern education, where students are frequently exposed to misinformation and need the skills to assess the validity of information they encounter.

V. DISCUSSIONS

The study of basic astronomical concepts has been carried out repeatedly [4, 9]. However, these studies were mainly aimed at studying the level of formed knowledge included in the standard. We were interested, first of all, in how adequately, on the basis of existing ideas and knowledge, students are able to evaluate the information they receive. The method of anonymous questioning was used (each student received a questionnaire). Most of the questions involved a choice of an answer or a monosyllabic answer. When composing the questions, it was taken into account that students are not familiar with the terms introduced in the astronomy course. This was taken into account when composing questions, as well as when analyzing the results of answers to those questions where a detailed answer was supposed. The most painful is the question of attributing part of the textbook material, traditionally studied in the course of astronomy, to optional for study. In this regard, the question of weakening the physical and mathematical component of the astronomy course has been raised more than once, in particular by E. P. Levitan, since the traditional astronomy program is overloaded and overly mathematized. Undoubtedly, this was one of the reasons for the crisis of astronomical education.

We consider it necessary to communicate elementary knowledge of astronomy to all students without exception, so we will use the phrase "astronomy course". At the same time, we recognize the need for a variable approach to the structure of astronomy teaching, which implies the presence of a mandatory (necessary minimum number of didactic units) and variable components. The goals of compulsory astronomy education for modern children and adolescents are highlighted by E.P. Levitan: to teach to give a correct explanation of the observed celestial phenomena, to acquaint with the modern astronomical picture of the world, to contribute to the formation of a humanistic scientific worldview, to use students' interest in astronomy as a motive for studying. The analysis of the results of the pedagogical experiment with a reliability of at least 95% confirmed the hypothesis of the study: if in the process of teaching astronomy, near-scientific knowledge and the means of their translation are the object of systematic attention, then this will contribute to the education of students with an adequate (critical) attitude to information received outside of school, as well as the prevention of the formation of quasi-scientific ideas.

VI. CONCLUSION

The analysis of epistemological and psychological approaches to the study of the foundations of near-scientific knowledge is carried out. It is generally accepted that these forms of knowledge fill a special cognitive niche in consciousness, and are not "deviations from the norm" or "inferior science". The existence of types of knowledge that are alternative to science is determined primarily by the natural limitations of the scientific method and rational cognition. It is proved that pedagogical approaches to near-scientific knowledge, limited by ignoring or a priori denial, are ineffective in the conditions of the modern information environment and are not able to form students' immunity from ignorant superstitions and misconceptions. Based on the analysis of methodological manuals on teaching astronomy for the elaboration of the issue of the interaction of school and extracurricular astronomical knowledge, it is concluded that the approaches adopted so far to overcome the formation of quasi-scientific knowledge are inadequate in the conditions of the modern information environment. It is revealed that the information of astronomical content transmitted by the modern information environment eclectically combines elements of various worldviews, which counteracts the formation of a scientific picture of the world. The distortion of scientific material, as well as the placement of pseudo-scientific information in popular media, is ubiquitous, from which it is concluded that it is inappropriate to rely on them in educational practice (use as a source of material). It is proved that the education of an adequate attitude to the information of astronomical content received outside of school is necessary. For this purpose, it is expedient to introduce a special content component containing, firstly, initial information about the essence, production and translation of not only scientific, but also near-scientific knowledge, and secondly, criticism of a number of common misconceptions, as well as near-scientific teachings of relevant subjects from the side of science. The methodology of education in astronomy lessons of orientation skills in the information environment, at the level of general and particular methodological issues has been developed.

The effectiveness of the developed methodology of educating an adequate attitude to information of astronomical content received outside of school has been experimentally confirmed, its positive effect on the ability to assess the truthfulness of information, as well as on the scientific nature of worldviews, has been shown.

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Author Contribution

All authors made an equal contribution to the development and planning of the study.

Conflict of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data are available from the authors upon request.

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