Силлогизмы и корректный индуктивный анализ в педагогическом исследовании как факторы, обусловливающие его научную ценность

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АННОТАЦИЯ

Введение. Критические вызовы представителей наук сильной гносеологической версии в адрес методологической невыстроенности педагогики опосредуют необходимость грамотных ответов педагогов-исследователей научному сообществу. Их основой может стать нахождение логического контента, адекватного сложности и многоплановости объекта исследования наук об образовании. Такое теоретическое построение будет способно помочь учёным конструктивно и грамотно осуществлять педагогическое исследование и защищать его результаты.

Целью статьи является выявление и обоснование перечня компонентов классической логики, корректное использование которых позволяет учёному получить и грамотно обосновать научному сообществу ценный авторский результат.

Методология, материалы, методы. Логико-содержательный анализ работ из области классической логики и методологии современного гуманитарного познания (1) и сопоставление оценок зарубежных методологов с анализом методологической корректности отечественных педагогических работ (2) позволили выявить и систематизировать тот пласт логического знания, который с учётом всех особенностей объекта познания педагогики обеспечивает возможность сделать выводы: а) о корректном предъявлении результатов и методов их получения научному социуму; б) о способах избегания выявленных типичных логических ошибок в процессе научного поиска.

Результаты. Выявлены типы силлогизмов, позволяющих конструктивное использование в сфере исследования образования: modus ponens, простой modus tollens и два сокращённых (энтимема, эпихейрема), а также силлогизм ограниченного использования в сфере наук об образовании modus tollendo ponens. Обоснованы два метода причинно-следственного анализа, которые с учётом специфики объекта исследования педагогики позволяют диагностировать причинную связь между объектами и феноменами: метод единственного различия и метод сопутствующих изменений. Результаты в данной части работы добавлены типичными ошибками в педагогике: поспешное обобщение, неправомерная аналогия и обозначение одной из причин исследуемого феномена в качестве единственной.

Научная новизна. Выявление, обоснование и систематизация логического контента, позволяющего получить конструктивный результат при исследовании разных сфер образования и грамотно обосновать его научному сообществу.

Практическая значимость. Разработаны конкретные логико-методологические ориентиры научного дискурса в сфере наук об образовании, способные стать частью учебных пособий по выполнению научно-квалификационных работ в системе педагогического образования на различных уровнях (бакалавриат – магистратура). Предложена и обоснована часть методики экспертизы качества педагогических исследований.

КЛЮЧЕВЫЕ СЛОВА

силлогизмы широкого и ограниченного применения, причинно-следственный анализ, метод единственного различия, метод сопутствующих изменений, аналогии в педагогическом поиске

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Syllogisms and Corrective Inductive Analysis in Pedagogical Research as Factors Determining Its Scientific Value

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ABSTRACT

Introduction. Critical challenges from scholars with strong epistemological approaches to the methodological inconsistency of pedagogy necessitate competent responses from educational researchers to the scientific community. These responses can be based on identifying logical content that adequately reflects the complexity and multifaceted nature of the object of study in the educational sciences. Such a theoretical framework will help scholars constructively and competently conduct pedagogical research and defend its results.

The aim of this article is to identify and substantiate a list of components of classical logic, the correct use of which allows a scholar to obtain and competently substantiate a valuable original result to the scientific community.

Methodology, Materials, and Methods. A logical and substantive analysis of works in the field of classical logic and the methodology of modern humanities knowledge (1) and a comparison of the assessments of foreign methodologists with an analysis of the methodological correctness of domestic pedagogical works (2) made it possible to identify and systematise that layer of logical knowledge which, with regard to all the characteristics of the object of pedagogical knowledge, enables one to draw conclusions: a) about the correct presentation of results and methods for obtaining them to the scientific community; b) about ways to avoid the identified typical logical errors in the process of scientific research.

Results. Syllogism types that allow constructive use in educational research are identified: modus ponens, simple modus tollens, and two abbreviated syllogisms (enthymeme, epicheireme), as well as a syllogism of limited use in educational sciences, modus tollendo ponens. Two methods of cause-and-effect analysis are substantiated, which, with regard to the specific nature of the object of pedagogical research, allow for diagnosing the causal relationship between objects and phenomena: the method of single difference and the method of concomitant changes. The results in this part of the work are supplemented by typical errors in pedagogy: hasty generalisation, invalid analogy, and designating one of the causes of the phenomenon under study as the sole cause.

Scientific novelty. Identifying, substantiating, and systematising logical content that enables constructive research results in various areas of education and their competent justification to the scientific community.

Practical relevance. Specific logical and methodological guidelines for scientific discourse in the field of educational sciences have been developed, which could become part of teaching aids for completing research qualification projects in pedagogical education at various levels (bachelor's and master's degrees). A methodology for assessing the quality of pedagogical research has been proposed and substantiated.

KEYWORDS

syllogisms of wide and limited application, cause-and-effect analysis, method of single difference, method of concomitant changes, analogies in pedagogical research

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INTRODUCTION

UNESCO and a number of other international organisations, emphasising the role of education as the primary means of transmitting a nation's intellectual and spiritual potential, pay particular attention to a considered critical analysis of the state of various segments of education and the development of scientifically grounded strategies for its transformation in the complex contemporary conditions. In particular, one of UNESCO's documents states: "We need a more intelligent, nuanced view of education and schooling that builds on systems and complexity theories and humanistic educational approaches" [1, p. 5]. This, in particular, necessitates the application of pedagogical conclusions and due methods used to justify them to the sphere of formal logic. Such a procedure involves a critical analysis of the extent to which pedagogical conclusions comply with the criteria for correctness of inferences, generalisations and analogies, as well as a causal analysis within a logical framework. Furthermore, it requires sound methodological reflection on the specific nature of all the mentioned procedures, with regard to the distinctive basics of educational science.

The works by epistemologists and methodologists of scientific knowledge over the past two decades firmly state that value-based content is being increasingly incorporated into scientific discourse; in particular, the cliché "scientific knowledge is valuable" is closely linked to the methodological accuracy of its results and the process of their acquisition. At the same time, the process and results of pedagogical research continue to face extensive, many-sided criticism from representatives of exact and technical sciences, as well as from scientific methodologists – both regarding the terminological framework and the presentation and justification of the obtained results. Numerous presentations on this subject by scholars at academic conferences and round-table discussions do little to alleviate the severity of the problem; the same concerns regulatory documents from the State Commission for Academic Degrees and Titles of the Russian Federation, monographs, and methodological articles that propose and justify the correct methodological status of pedagogical research papers. However, this stream of criticism often contains both well-founded and "misplaced" challenges, and very rarely includes objections and claims against authors that are based on the well-established standards of humanistic logic. This latter circumstance has led us to analyse the works of our predecessors directly related to the logical content of pedagogical knowledge and the methods of its acquisition, and to conclude that this field of research has, to date, been explored only to a very limited extent. This is particularly true when compared with the coverage of this subject by methodologists working in the sphere of mathematical and natural science. One of the presumed reasons is the complexity and multifaceted nature of the object of pedagogical research and the resulting difficulties in categorising and formalising both basic concepts and the process of deriving and justifying the patterns governing educational phenomena. Consequently, the accurate description of the process exploring pedagogical reality in the language of logic remains a complex and as yet unresolved task. It follows from these premises that research in this area could both identify some proven methods for enhancing methodological rigour in pedagogical research and provide compelling arguments to address the criticism received.

In view of all the above-noted circumstances, this article aims to identify and justify a list of components of classical logic which, when correctly used, would enable us to derive and competently substantiate the valuable original findings for the scientific community. The hypothesis of this study is that, despite the difficulties involved in describing the pedagogical object and "incorporating" its properties and parameters into logical procedures, a meticulous analysis of the components and norms of classical logic will make it possible to demonstrate and systematise: a) the segment of logic accessible to contemporary educational research and the methods for its correct application; b) the extent of reliability of the derived results, with due substantiation. The research team focuses its attention on the substantive field of education; the reached conclusions may serve merely as a starting point for similar studies in other areas of humanitarian knowledge.

LITERATURE REVIEW

The chosen research subject led to the inclusion of works by the forerunners of two major categories of academic sources in the review. The first one comprised studies by foreign authors

where classical logic and its constituent part (the theory of argumentation) were examined in the context of the problem of developing critical thinking among students in general and university-level professional education, as a key personal quality for graduates seeking to achieve professional and personal self-realisation in contemporary society. Such sources include works devoted to: a) the development of critical thinking in mathematical education by Mahmoud [2]; b) sound argumentation in school-based educational dialogue by Rapanta and Macagno [3]; c) the role of various logical operations in the development of theoretical thinking by Vartiak et al. [4]; d) the pedagogy of dialogue using critically charged questions by Nussbaum et al. [5], e) interactive learning focused on the analysis of oppositions by Howe [6], f) the analysis of students' learning outcomes in the process of applying the argumentation theory by Iwuanyanwu [7], g) the measurement of the maturity level of argumentative reconstruction skills by Berkle et al. [8], h) the integration of argumentative skills into students' extracurricular activities by Gonzales et al. [9], i) the use of dialogue to foster critical thinking by Cui and Teo [10] and Tong and Ding [11]; (k) the development of logical thinking in university education by Soares et al. [12] and Bordás and Debrenti [13]. These works reflect a broad range of strategies and components of critical thinking and identify a list of methods and techniques for its formation and development – both in the study of various disciplines and in extracurricular activities. The works by Morrow [14] are devoted to the development of critical thinking among schoolteachers and university lecturers. The dialectic relationship between critical thinking and creativity is discussed in the works by Ellerton and Kelly [15] and Rapanta [16]. Educational analytics in online discussions and educational games is explored in the research by Martínez et al. [17]. Pedagogical support for the development of argumentation skills in various segments of higher education is presented in the works: a) related to educational games by Lee and Samanta [18], b) devoted to argumentation in the process of postgraduate students preparing their theses by Kilpelä et al. [19], c) discussing logical components in mathematical education by Munyati [20]. The study by Kizi [21] is devoted to the development of logical thinking in pedagogical practice. The work by Seif [22] is devoted to the links between logic and higher-order intellectual skills; its pedagogical support is discussed by Altun and Ozsevgec [23]. The significance of fostering logically sound critical thinking strategies in learners, as reflected in the representative list of sources, has led us to conclude that everything described in the cited texts requires, as a necessary condition, a thoughtful reflection on research in the sphere of education from the perspective of the principles of classical logic. In this regard, the authors placed particular emphasis on the problems of justifying pedagogical outcomes and the methods used to achieve them.

This circumstance led us to turn to the second category of academic sources related to the assessment of methodological accuracy in contemporary research in the field of education. This topic is the subject of Ennis's work [24]; the aspect of causality is examined in detail in the works by Zenker [25]; the issues of stylistic correctness of various argumentation types are presented in the texts by Irawan and Valentina [26] and Boogaart [27]. The research potential and prospects for the development of educational sciences are presented in greatest detail in the work by Leś [28]. Substantive and logical shortcomings, as well as some methodological inaccuracies in research on educational topics, are made explicit through a series of theses presented in the works by a number of authors. The most characteristic flaws in dialogical pedagogy are examined in the text by Nussbaum et al. [29]. The work by Rapanta and Macagno [30] is devoted to logical errors in the humanities. The issue of logical flaws in student discussions is described in the texts by Gronostay [31] and Inayah et al. [32]. The most common logical errors in academic writing have been studied by Luchini and Rasini Robles [33]. The most common logical errors in academic writing have been studied by Rapanta [34] and Sarvary et al. [35], whilst other logical errors are described in the works by Toychiyeva [36] and Wong [37]. In many of the listed texts, causal analysis and analogies fall within the content that reflects inadequate methodological representation in pedagogical research. A comparison of foreign researchers' findings with the authors' analysis of domestic pedagogical works of varying scope and content has confirmed the conclusion that they are characterised by an evident deficiency of logical reflection elements – both in terms of assessing the validity of the proposed conclusions and the employed methods and techniques of scientific inquiry. The thesis regarding the relevance of the research undertaken by our team of authors has been corroborated by the findings of foreign scholars, Snaza [38] and Letiche [39], which clearly identified some serious methodological shortcomings.

METHODOLOGY, MATERIALS AND METHODS

One of the main methods employed was the analysis of works (monographs and articles) on classical logic recognised within the scientific community, with a view to assessing the possibility of achieving logical accuracy in the humanities as a whole, and in the sciences exploring education issues, in particular. The list of academic sources also included articles by foreign authors in which: a) the unsatisfactory state of pedagogical science (known in English as "educology") was highlighted and substantiated, specifically in assessing the compliance of various parameters with the requirements of methodological correctness, including the transparent definition of objectives and problems, due formulation of hypotheses and research methods, and sound reflection on the obtained results; b) various methodologies and techniques for developing critical thinking in university education were discussed – as one of the most significant qualities of a university graduate preparing for full professional and personal self-realisation in the modern world. The conclusions drawn from this list of works necessitated a review of domestic pedagogical research published in monographs and journals indexed in the Scopus database, Web of Science, Russian Science Citation Index (RSCI) and the RF State Commission for Academic Degrees and Titles. The analysis focused on the extent to which authors adhered to logical norms of scientific discourse when justifying their findings and the methods used to achieve them. A comparison of foreign methodological texts and domestic pedagogical works covering a broad spectrum of research interests made it possible to identify and systematise the segment of classical logic that can be fully applied in the science of education following from the specific nature of its subject matter characterised by an exceptionally complex nature and ensuing difficulties in quantitative and qualitative categorisation and formalisation. This systematisation has made it possible to identify, as key areas for further research, the issues of correct use of various syllogisms and those pertaining to the methodological accuracy of all components of causal analysis. By focusing on these two identified components, the team of authors has substantiated the methods for the correct use of widely used syllogisms and those of limited application in educational research, and has also identified the relevant typical errors of educational researchers. Relying on the list of causal analysis methods, the authors succeeded in identifying and justifying two of them, most suitable for educational science and for pinpointing the logical errors found in a wide range of works. Particular attention was paid to the positive and negative aspects of using the method of analogy, given its widespread use. The research culminated in conclusions summarising the findings reflecting the necessity and the methods of structuring pedagogy in a correct logical format (1), and the objective reasons for its lagging behind sciences with a strong epistemological foundation, in this regard (2). The described methodological toolkit and its specific application, as presented in the text of this article, enable the reader to reproduce it for similar research in other humanities.

RESEARCH FINDINGS

As is clear from the introduction, in justifying the theoretical and applied value of the results proposed by an educator-researcher or a research team, we shall emphasise that a specific assertion, inference or conclusion is contingent upon one or several correctly implemented logical procedures. In these terms, it is essential to refer to the fundamental law of reasonable cause (facts that enable a researcher to formulate their assertion, and conclusions of their predecessors they draw upon in their own research), which was described by us in detail in the previous articles. Based on an analysis of pedagogical literature, as well as a number of works in the domain of philosophy of science, we do argue that syllogistic operations, along with a wide range of inductive procedures, are among the most relevant to the field of education, yet insufficiently covered in the scholarly literature.

Syllogisms in pedagogical research. We shall proceed to exploring the logical framework of the ideas, concepts, theoretical constructs, teaching methods and technologies put forward in the course of educational research, and their comprehensive justification, by examining syllogistic structures. As is well known from classical logic, syllogisms are inferences derived on the basis of two propositions (affirmative or negative, with varying degrees of certainty); the resulting third proposition is subject to analysis in terms of its logical correctness. Simple constructive syllogisms, commonly referred to

as "modus ponens", include cases where both "premises" and the inferred conclusion are affirmative. For instance, it has been established that the inclusion of certain tasks in the curriculum enables school pupils and students to discover facts previously unknown to them and is therefore of positive value (deserving of the attention of the educational community) – the first premise. It has also been established that if the process of solving a particular educational task trains learners' mental abilities, then such tasks are valuable – the second premise. The following statement follows from these two premises: since any educational task either introduces learners to new facts (constituting a subjective micro-discovery) or trains their mental abilities, then any educational task deserves attention. The validity of such a syllogism depends on the extent to which the scientific community recognises the truth (validity) of the initial premises. In particular, the given example excludes considerations related to the subjective difficulty of tasks for specific types of learners and thus significantly affecting their usefulness; therefore, this type of syllogism in pedagogical research generally requires supplementary considerations (statements, assumptions).

It is appropriate to extend this type of syllogism with its antithesis. In logic, this is known as "simple modus tollens" – it encompasses cases where both the initial premises and the conclusions drawn from them are negative (destructive) in nature. For instance, a developer modifying the existing educational content within a specific academic discipline is planning to supplement what has already been included with a new, extensive block of material. In this case, it is necessary either to increase the number of academic hours allocated to the discipline (academic subject) (premise one), or to remove a particular area of knowledge or skill from the existing curriculum (premise two). It follows from these two premises that neither option can be implemented. If the proposed expansion of the curriculum is deemed significant for the educational results of graduates from higher or secondary educational institutions, then this conclusion is supplemented by the assertion that alternative options should be sought for its inclusion in the curriculum.

Classical logic also recognises abbreviated syllogisms, among which the enthymeme stands out; it will be illustrated with a simple example. Any pedagogical abuse of the individual is negative; if a teacher resorts to violence, they deserve condemnation. Another well-known abbreviated syllogism is the epicheireme, illustrated by the following example. Lying deserves condemnation because it is immoral. Therefore, for instance, a teacher's reliance on artificial intelligence to complete an assignment intended for independent work is reprehensible, as it misleads the examiner (who assesses the work). The three syllogistic constructions cited above, which are common in educational research, are undoubtedly somewhat schematic and, in most cases, require the researcher to immerse themselves in the specifics of the situations being explored (whether academic or practical), to supplement "pure" logic with a substantive analysis, and to contextualise the logical steps and the obtained results.

Let us now turn to examples of syllogisms of limited application in the sphere of education. One such syllogistic structure is the modus tollendo ponens. In this syllogism, one of the premises negates all the components of division, as identified at the outset, with the exception of one – and this constitutes the conclusion in the affirmative modality. Let us construct one possible illustrative example from the domain of educational research. A negative result in a pedagogical experiment may be due to one of the three circumstances: an erroneous or insufficiently developed conceptual design (1); a poorly developed methodological model for its implementation in the educational process (2); various deviations from the methodological model that occurred during the experiment, in particular, the impact of unforeseen secondary factors (3). One might, of course, assume that research has clearly established that two of the cited circumstances (for instance, the first and the second) are not the causes of the negative experimental result, and, by the process of elimination, identify the third one as the cause. However, scientific reality shows that such a stance is quite rare in the area of education. Applied to the example under consideration, this means that in most cases, a negative experimental result in the field of education is caused not by one, but by the three factors at once, albeit with varying degrees of "contribution" to the result.

We consider it necessary to supplement this section with an example of typical syllogistic fallacies. An analysis of academic texts on pedagogy reveals a high frequency of errors associated with the destructive complex syllogism "modus tollens". Let us provide a hypothetical example, deliberately simplified, so that the essence of the argument is clear to as many readers as possible. For a university

student, studying may form part of their core life values. The researcher concludes from this that special incentives from the lecturer are in this case unnecessary. On the other hand, the opposite is often observed: studying is not a core value for the student; they try in every way to meet the curriculum in the most minimal way possible, sometimes resorting to deceiving the lecturer. In this case, the lecturer's incentives are practically useless. The researcher concludes from these two facts that the teacher's incentives are either superfluous or useless. However, the author of this dilemma-based conclusion makes a mistake: the conclusion he proposes would only be valid if a "love" of learning and an "aversion" to it constituted the entire range of possibilities. This is not the case in the given example: for instance, a student may display an attitude towards learning that does not fall into either of the two extreme cases mentioned. In most such cases, pedagogical encouragement is entirely appropriate, for instance, when a student's sustained interest in studying is still developing, and instead of aversion, there is a lack of motivation to overcome the inevitable cognitive barriers.

Correct inductive logic in pedagogical search. Like in any field of the humanities, inductive procedures are far more common in pedagogy than deductive ones. This means, in particular, that the validity of the premises does not guarantee the validity of the conclusion drawn from them – it can only be treated in probabilistic terms. Conclusions that are valid only for a specific, inevitably limited set of objects or processes may prove to be invalid (or valid only subject to additional conditions, reservations or restrictions) for a wider range of objects or processes. Such a logical flaw in scientific discourse is sometimes referred to as hasty generalisation. Exploring the content of this section involves considering a wide range of inductive procedures in educational research, which are classified by classical logic as the transition from particular judgements to general ones, inferences by analogy, causal analysis and, inevitably (and particularly relevant to the field of education), goal-based justifications.

Let us begin by mentioning complete and incomplete induction. The former type is extremely rare in the domain of education, or is limited to trivial cases of no scientific interest. For instance, having recorded a particular indicator as being the same for each learner (participant in an educational experiment) individually and consistently, the experiment organiser concludes that all participants exhibit the level of personality trait or academic skill in question as correlating to the identified indicator. We have been unable to identify any examples of complete induction in education that differ in essence from the one above (neither independently nor in academic sources), so we can rightly claim that, in the overwhelming majority of cases in pedagogical research, one should resort to incomplete induction, whereby a pattern (property) identified within a limited sample of objects or processes is extrapolated to a larger sample. Naturally, such a procedure requires justification regarding the similarity of a property (quality, parameter) between the objects that have been directly examined and the ones to which the research conclusion is extended. The simplest examples of induction in educational research are statements such as the following: a) so far, the method of expert assessment has been used when reviewing works on methodology of education; therefore, this method should also be employed for the specific research (article, monograph) under consideration in the present case; b) traditionally, Spearman's test (or Wilcoxon's test, or the Mann–Whitney U test) has been used to assess the significance of differences in the performance of control and experimental groups of learners; therefore, in the specific case relating to the thesis under review, this test should be used as a guide; c) the case study method is traditionally used to teach … (a particular skill); therefore, it makes sense to recommend it to new aspiring researchers. All of the above is quite clear in terms of reliability of the drawn conclusions – they are probabilistic in nature, and no one is immune to a failure in the N + 1st case when using something that has proved successful in N cases. Among the simplest negative examples of induction in educational research are frequently encountered statements (both in verbal presentations and in academic texts), such as the following: there are no other ways, apart from those we have proposed, of helping learners acquire the desired socially and personally valuable skill or quality; there is no other way to justify the derived result (other than the one we propose), and a number of other similar statements.

Non-trivial inductive content in pedagogical research inevitably leads one to consider such an attribute as a scientific hypothesis. Educational methodologists who have addressed this issue point out that, in social sciences and humanities, a particular assumption about something previously unknown (in a sense, a discovery) cannot be made by means of "precise deduction" and, in the vast majority of cases, rigorous deductive procedures are partially integrated in inductive reasoning,

inferences, and conclusions formulated on their basis. Our further task will involve identifying various inductive procedures in pedagogical hypotheses of different types and bringing their results into a methodologically sound framework. In the monograph cited above, the authors classify hypotheses in the field of educational research based on an analysis of a representative body of pedagogical works and texts on methodology of science [40]. The first type comprises hypotheses on the nature of educational objects and phenomena, as well as the forms, levels and characteristics of their existence and manifestation in educational reality. The second type of hypothesis relates to assumptions about interrelationships (internal and external) that characterise the objects and phenomena under investigation. The third type involves identifying a set of diverse cause-and-effect relationships between pedagogical phenomena and objects, accompanied by the identification of pedagogical conditions and factors influencing their existence and development, as well as various psychological mechanisms. The fourth, widely prevalent type of pedagogical hypothesis is associated by methodologists with identifying the means and methods for achieving the positive pedagogical outcome under investigation (in accordance with the chosen subject area).

In the first type of hypothesis, the authors base their arguments on the knowledge previously acquired with varying degrees of accuracy: for instance, a widespread cognitive barrier, commonly used in educational practice, is attributed either to the poor formation of some element of knowledge required to solve the tasks set by the curriculum (or to its "loss" due to the length of time since it was first presented to the pupil or student, along with the lack of appropriate subsequent consolidation), or to the underdevelopment of some thinking skill (operation) that enables the solution of a curriculum-based task. In the following three types of hypotheses, the inductive format involves a range of techniques used in causal analysis known in classical logic, which is not classified by authors on classical logic as related to the identification of "purely logical relations"; however, it is included within the scope of studies by logic as a field of scientific knowledge. Therefore, the task of logical study of causality boils down to the systematisation and concise representation of reasoning patterns that enable one to link events (factors, circumstances) followed, with a certain degree of probability, by other related events. The task of logic as a science, in terms of studying causality issues, is further complemented by determining the extent of reliability of conclusions derived from such reasoning. It should be added that logicians distinguish a "strong causality ground, meaning that something which has a cause cannot fail to exist, and cannot be abolished or altered by any events or actions" [41, p. 208]. Logicians also distinguish a "weak concept of partial or incomplete cause", sometimes referred to as a partial cause, which contributes to the occurrence of the associated event only to a certain extent and, as a rule, only when combined with a number of additional circumstances. This latter concept is highly relevant to the multifaceted, inherently complex and, in some cases, difficult-to-formalise objects within the sphere of education. Like in other fields, the general approach to the problem draws on the methods used to identify causal relationships: exclusion, similarity, single difference, and concomitant changes.

The method of exclusion assumes that the researcher specifically excludes from consideration all possible circumstances and factors capable of influencing the course of the pedagogical phenomenon under study, except for one, which is suspected of being its cause. In actual research practice, this means the need to isolate the experimental sample of learners from the entire educational context, leaving them solely with the innovative teaching or educational methodology being tested – something that is hardly possible today and is unlikely to be possible in the future. The "method of similarity" proposed by the classics suggests that the researcher should observe the pedagogical phenomenon of interest in several situations and, in the process, identify the presence of some single factor, thereby making a well-founded assumption about it as the cause of the phenomenon under investigation. Such an approach is difficult to implement in the field of education. To illustrate this, let us consider a task requiring the identification of the causes of academic underachievement, based on a sample of students. The researcher may consider a number of circumstances as possible causes: no motivation to study (for instance, due to a random choice of university and degree programmes); an insufficient level of prior knowledge and skills required to master the university-level material; no suitable conditions for completing homework; the need to earn money to pay for tuition and the resulting lack of time to prepare for classes; and the presence of a hobby that takes up a significant amount of time outside of study hours. The researcher can easily record the presence or absence of these factors in a special table based on questioning and observations, which will enable the frequency of each to be identified and compared. However, the factor for which this indicator is the highest can be regarded as merely one of the causes of academic underachievement – a partial cause

(dominant amongst the others, which cannot be ruled out). A similar study could well be carried out to investigate the reasons why editorial boards of journals reject authors' articles. The list of reasons for rejections may include: the insufficient empirical support of the conclusions; the article's topic not being in line with the journal's scope; the use of material without citing the authors; the insufficient logical rigour of the presented conclusions; the authors' poor familiarity with the works of their predecessors on the chosen subject; limited publication experience; and a number of other factors. However, in this case too (like in the previous one), it is only possible to identify the dominant (partial) reason for editorial rejections, as based on an empirical survey of a sample of authors who received editorial rejections, drawing on the highest frequency.

The "method of single difference", included in the list of procedures for causal analysis, requires that the factor of interest to the researcher be included once as an element affecting the system under study, but be excluded the next time. If, in the first instance, the event that follows really takes place, whereas in the second case it does not, then this factor may be considered as a cause of the event of interest to the researcher. In the sphere of education, this can be achieved by comparing the educational outcomes of two study groups: an experimental group (where the experimental methodology was applied) and a control group, where teaching was conducted using traditional methods. Naturally, with this approach, it is necessary for the initial level of a skill or personality trait considered by the author in the two groups to differ by a statistically insignificant margin – to this end, it is advisable to introduce some quantitative characteristic (a parameter showing the maturity of a skill or a trait) into the analysis and apply one of the comparative procedures known in mathematical statistics. Despite all the noted difficulties, we believe it is possible to assert that the single-difference method is practically the only tool which can enable a researcher, in case of correct application, to identify one of the possible causes of the phenomena under investigation in the field of education. Although, to be fair, it should be noted that the fourth method (of concomitant changes) can also be used, albeit infrequently – this is similar to a single-factor analysis of variance, where the impact on the object is split into several stages: initially it is minimal, then the impact intensifies and, finally, reaches the maximum possible level. As applied to research in the area of education, this means introducing only a few elements of the innovative methodology at the first stage, increasing the extent of incorporation into the educational process at the second stage, and implementing it fully and intensively at the third stage. In doing so, mathematical statistics sometimes allow one to determine, with a specific degree of probability, whether the parameters characterising the educational outcome have changed significantly or only slightly. It should be particularly noted that, in many cases, the use of two methods adapted to the domain of education does not yield an unambiguous conclusion on the sole cause of the observed phenomenon – as a rule, it is possible to assert that only one of the possible causes has been identified.

When discussing inductive hypotheses (both in the case of enumerative induction and causal analysis), it is also necessary to mention that their formulation marks a transition from sensory images of objects and phenomena of educational reality in the researcher's mind to their "empirical representations" (empirical patterns), which filter out a multitude of properties and parameters of no interest to the researcher and which are expressed in scientific language (through various types of definitions). At a certain stage, when empirical constructs have stood the test of time, various theoretical constructs are developed on the basis of inductive inferences; pedagogical concepts are formulated, and the scientific glossary is enriched with new terms and concepts.

As noted at the beginning of this section, inductive analysis involves inferences by analogy, which is frequently used in educational research. Among the examples from the history of pedagogy that confirm this premise is the development and introduction of problem-solving teaching into the educational process. In particular, in 1975, a monograph "Problem-Solving Teaching: Key Issues in Theory" by M.I. Makhmutov, an academician of the USSR Academy of Pedagogical Sciences, was published, in which the author highlights in detail the shortcomings of the explanatory-illustrative method of teaching, which draws on schoolchildren's perception of educational information, its understanding (internalisation) and reproduction at the teacher's request. This is substantiated by the fact that reproductive skills alone are definitely insufficient for school leavers in their future social life and professional activities. The author then attempts to justify a project aimed at stimulating pupils' educational and cognitive activity, based on an analogy between the scientific-research thinking of professional scholars and that of school pupils. The core of the author's concept is to enrich pupils' educational activities with components such as contradiction, problem, hypothesis, and a number of others. Despite the significant differences between professional scientific thinking and educational

acquirement, the author has succeeded in identifying and accurately defining the extent of their similarity, and in proposing a conceptual model of school education based on this similarity, as well as the related methodological solutions. The identified similarities between scientific and educational cognition have, in particular, made it possible to include the term "problem situation" in the didactic glossary – as a state of intellectual difficulty experienced by a pupil who is unable to solve the task set by the teacher using only familiar methods. The problem situation (according to Makhmutov) is inevitably associated with a state of emotional discomfort artificially created by the teacher in the pupil due to the inability to complete the proposed task: such a state is intended to serve as a trigger for active engagement in learning activities, something akin to scientific search.

The inductive "approach", as discussed herein, put forward by this scholar at the end of the twentieth century, was, to a certain extent, accepted by the academic community – after some time, a number of other Russian scholars proposed their own versions of problem-solving teaching, and their work led to several interesting methodological innovations that found application in educational practice. At the turn of the 21st century, Russian higher education pedagogy also took up this idea, recognising the importance of developing problem-oriented teaching methods, as well as the fact that the scope for such approaches in the university sector was much broader than in general secondary education.

Despite all the merits of the pedagogical innovations under discussion, we consider it necessary to emphasise that, in the case under consideration, the method of analogy has also demonstrated the probabilistic nature of the results obtained through its use. Both the developed theoretical constructs and the practical application of problem-based teaching methods have revealed the inevitable difficulties involved in their implementation within the educational process. These include: the time required, the difficulty of fitting these methods within the constraints of the teaching timetable, and the need for a higher improvisational resource of a teacher using the technology in question in their practice. This provides grounds for reiterating the argument that the method of scientific analogy has very limited evidential potential.

Another example of inductive scientific content linked to analogies in pedagogical research is the idea of managing the learning activities of school pupils or students. The authors who proposed and developed this idea introduced the terms from general management theory into the pedagogical scientific glossary: controlled object, controlling influence, controlling elements, and feedback. In the approaches known to us from literature, the learner is the object of control (a school pupil, a student, or an adult undergoing training within a professional development system), whilst the controlling element is represented by the teacher's various pedagogical endeavours. The feedback is shown by learners presenting their completed tasks to the teacher, along with the ensuing dialogue, which provides an indication of the adequacy of the controlling actions and the learners' response to them. The authors have attempted to implement this analogy instrumentally by constructing mathematical equations, for instance, as proposed by Solodova [42]. The achieved result cannot so far be considered satisfactory: whilst focusing the idea of managing students' learning activities on the process of assimilating the educational information provided by the teacher, the cited monograph proposes a differential equation in which the left-hand side records the time derivative showing the difference between received and assimilated information, summed with the information perception coefficient multiplied by the aforementioned difference. The time lag between the moment of receiving information and the moment of its assimilation is taken into account. The right-hand side of the equation demonstrates a quantitative measure of the information flow conveyed by the teacher. The general approach in the proposed model is clear; however, no solution is offered for the specific case; the methods estimating the amount of information are not discussed; and the ways to derive the coefficients included in the equations are not addressed as well. Thus, the problem requires further research.

An analysis of a large body of doctoral research in educational disciplines also reveals a significant frequency of unfounded analogies in cases where conceptual models, as well as the teaching and educational methods and technologies they employ, which have proved successful in some singular segment of the education sector, are transferred to another segment without due criticism (mechanically, automatically, with no regard for a host of significant differences). For instance, an approach that has yielded significant positive results in primary education is transferred to secondary education without major modifications, or a concept successfully implemented in higher education is extrapolated to adult education.

As was noted at the beginning of this section, inductive procedures in educational sciences are inevitably linked to a component of logic known as goal-based justification: the positive significance of a particular outcome (for example, the learner's increased level of knowledge, skills, or personal qualities) dictates the need to develop due means for achieving it within the educational process – naturally, with regard to a host of related processes and circumstances. Consequently, the significance of many inductive arguments in the field of education is closely linked to the significance of the objectives set for the educational system by societal demands.

Thus, the content of this section allows one to assert that, being devoid of the possibility to make full use of deductive procedures in the process of acquiring new knowledge (as is done in mathematics, technical sciences and some areas within the natural sciences), pedagogy is naturally oriented towards an inductive approach, and all procedures traditionally included within its scope may, to a greater or lesser extent, be of interest to researchers in a broad variety of segments and aspects of the educational process. However, it is important for the researchers – and the academic community reviewing their findings – to assess the extent to which inductive generalisations and extrapolations are used correctly; the same concerns causal analysis and the application of the method of analogy. This correctness encompasses specific methodological requirements, which are presented and substantiated in this section.

DISCUSSION

This section includes a number of additional comments on the content of the previous section. To begin with, we shall cite some specific, widespread instances of violation of logical norms in pedagogical research related to syllogisms. In particular, in doctoral research, when formulating the methodological framework and substantiating the relevance of chosen subjects, the following line of logical reasoning is used: a) the social demand for a specific segment of education identifies the need to develop a particular area of knowledge, skill or personal quality (1); b) an empirical study of a representative educational sample reveals the level of maturity of socially valuable content that does not match the social demand (2); c) the chosen subject, aimed to meet the social demand, is relevant. This final conclusion must be supplemented by at least three points. To conclude on the relevance of developing the chosen topic, the researcher should: a) submit an overview of works of varying scope for expert review, those already completed in a chosen subject area (or in thematically related segments thereof); b) identify the shortcomings in the conclusions of previous researchers; c) if it transpires that their conclusions are entirely sufficient, well-founded, and constructive, investigate the reasons why they have not been implemented in educational practice.

Now let us turn to the thesis that "deduction alone must be the criterion for correct induction, that is, the possibility of deriving facts purely logically from the premises of induction" [43, p. 50]. At this instance, we should inevitably turn to deriving consequences from an inductively obtained conclusion, and their verification. For example, we consider an assertion (a generalisation based on quotations from well-known psychologists and from personal life experience) stating that those who think clearly also express themselves clearly. The "touchstone" of the teacher's clear thinking is their ability to convey the full content set out in the syllabus to the students – here, the results of assessment of students' knowledge and skills serve as an indicator confirming the clarity of pedagogical thought. The logical structure of this statement is simple: if the first premise is true, then the second premise is also true. However, logicians in this case point to the "asymmetry" between the direct and inverse inferences: the inference from the premise to the conclusion is valid, but the inference from the conclusion to the premise is merely probabilistic. These illustrations must be supplemented by the observation that, in the overwhelming majority of works on pedagogy (excluding studies on the history of pedagogy, comparative pedagogy, and some methodological works), the educational methodologies (and, in some cases, technologies) derived from a conceptual model are put into practice, and the obtained results serve as indicators of their effectiveness, as well as scientific and practical value. In some cases, the results sought by researchers prove unattainable or only partially attainable, which necessitates a series of steps that cannot be defined unambiguously, to be outlined below.

Firstly, it is necessary to assess the correctness of the experimental procedures in terms of compliance with all points of the developed methodologies or technologies, as well as the possible interference of certain secondary factors in the experimental process, which significantly skew the

result in a negative direction and which were not taken into account beforehand for various reasons. If such circumstances are absent (do not affect the outcome of the verification experiment), then the second step may involve analysing and adjusting the methodological model constructed to implement the research design, followed by its repeated experimental validation. It cannot be ruled out, however, that even in this case, no significant positive changes will occur; then the third step should be taken – the revision of the conceptual framework, which will inevitably lead to substantial changes in the methodological models it underpins.

This last step is quite labour-intensive and involves a certain semantic reworking of the initially formulated research hypothesis, which, in turn, entails "immersing" its original version in some unprovisioned aspects of the educational reality (which may well have influenced the recorded negative result). Such painstaking research work is necessitated by the exceptional complexity and multifaceted nature of the object of pedagogical research. In particular, the transformation of the initial hypothesis (which, in this case, should be accorded the status of primary, working, or preliminary) may relate to some unaccounted-for psychological characteristics of learners – subjects of the pedagogical intent (with a focus on the characteristics of their thinking, volitional and emotional spheres), or to the insufficient maturity of the initial knowledge and skills of the experiment participants, necessary for the full mastery of material the researcher proposes. Among the factors initially overlooked is inadequate teacher training in terms of pedagogues' understanding of the general and specific aspects of the educational methodology proposed for testing, as well as their lack of motivation for considered experimental work. In some cases, the modification of the initially proposed hypothesis is aimed at supplementing the set of pedagogical conditions invariantly included in it for achieving the intended result. Among these, the educator should distinguish between: a) those that are essential, without which the entire endeavour is doomed to failure; b) those that are not strictly necessary, but are regarded as desirable; c) those that are sufficient; d) those that are necessary but insufficient for the realisation of the concept.

To conclude the discussion of the results, it should be noted that even a positive result achieved during the testing of the innovative teaching method cannot be regarded as definitive – the increase in the level of knowledge or skills achieved in a certain experimental sample may yield a biased result in another sample (and require correction), which is entirely consistent with the methodological premise on the probabilistic nature of any inductive inference.

CONCLUSIONS

The research conducted and described herein provides grounds for formulating a number of conclusions:

1. The value of the results and methods of educational research is closely linked to the scientific community's understanding of the logical framework of the propositions put forward and the methods used to arrive at them: the correctness of the employed syllogisms, the soundness of the cause-and-effect analysis, as well as the validity and awareness of the limitations of the applied analogies.

2. The list of syllogisms most suitable for research in the field of education includes: a) modus ponens; b) simple modus tollens; c) abbreviated syllogisms (enthymeme and epicheireme). Modus tollendo ponens should be classified among the syllogisms of limited use.

3. Of the four methods of causal analysis established by classical logic, the method of single difference is the one most suitable for application in pedagogical research. In certain cases, where it is possible to mathematically represent the learner's educational outcome, the method of concomitant changes, as defined by classical logic, proves to be applicable. The most common errors are: a) presenting an identified circumstance as the sole cause of the observed nature of a pedagogical phenomenon – rather than correctly identifying it as one of several possible causes; b) the unjustified expansion of the scope for the use of analogies.

4. In terms of the rigour and unambiguity of logical conclusions, pedagogy, for objective reasons (the complexity of the nature of objects and phenomena, difficulties in categorising and formalising them, and the imprecise glossary), falls short of sciences of a higher epistemological order; however, this circumstance cannot serve as a subject of valid criticism thereof.

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