

Improving the Methodology for Developing the Professional Competence of Future Teachers Based on Digital Educational Technologies

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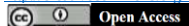
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ABSTRACT

This article examines the methodological foundations and practical possibilities of developing the professional competence of future teachers through the effective integration of digital educational technologies into the teaching and learning process. The study focuses on the transformation of traditional pedagogical and cognitive methods under contemporary digital learning conditions and considers how digital tools can strengthen the formation of professional, analytical, creative, and practical competencies among students of pedagogical institutions. Particular attention is paid to the use of observation and experiment, comparison, analysis and synthesis, abstraction, generalization, specification, classification, and criterion-referenced assessment as important methodological tools in the educational process. The study explores how these methods can be supported and enhanced through interactive digital environments, multimedia resources, digital simulations, online learning platforms, electronic assessment systems, and other information and communication technologies. The article also examines the importance of establishing interdisciplinary connections, strengthening the relationship between theoretical knowledge and practical activities, and organizing learning around innovative technologies and practically oriented tasks. The proposed methodological approach is based on the principle that digital technologies should not merely replace traditional teaching methods but should meaningfully enhance learners' cognitive activity, independent learning, problem-solving abilities, critical thinking, creativity, and ability to apply theoretical knowledge in practical situations. The results indicate that the systematic combination of traditional cognitive methods with digital educational technologies creates more favorable conditions for active and conscious learning, improves the effectiveness of instruction, and supports the development of professional competencies required of future teachers. The study further demonstrates that digital assessment tools can provide more systematic and criterion-based evaluation of students' knowledge, skills, and competencies while generating feedback that can be used to improve subsequent instructional activities. The findings are relevant to higher pedagogical education institutions seeking to modernize teacher-training programs, improve the quality of educational processes, expand opportunities for independent learning, and prepare future teachers to work effectively in increasingly digital educational environments.

Introduction

The disciplines that make up specialized, mathematically oriented training are built around the spatial forms of material objects and the quantitative relationships that connect them, and understanding these relationships has always required more than the passive memorization of formulas or finished results. Establishing such relationships in a rigorous way requires researchers and teachers alike to rely on a body of general scientific methods of inquiry — tools that are equally indispensable for producing new knowledge and for transmitting it to learners in a form that they can genuinely internalize. In the context of rapidly expanding digital educational technologies, the question of how these classical methods of inquiry can be reorganized, scaled, and enriched through digital means has become

increasingly central to the modernization of pedagogical education, and it is this question that motivates the present article.

Among these tools, observation and experiment occupy a central place as empirical methods drawn from the natural and experimental sciences, and they remain the starting point from which learners first encounter the regularities that specialized disciplines are meant to explain. Yet experimental confirmation alone cannot serve as an absolute criterion of truth, since a result confirmed under one set of conditions may not generalize automatically to another; this is precisely why teaching cannot stop at the level of empirical demonstration. If the study of specialized disciplines is understood as a form of conscious activity rather than a passive reception of facts, teaching must go beyond transmitting ready-made knowledge: it must also equip learners with methods of cognition — observation and experiment, comparison, analogy, induction and deduction, analysis and synthesis, generalization and specification, and classification — through which hypotheses can be formulated independently and subsequently verified as correct or incorrect through the application of other, complementary cognitive methods [1]. It is precisely this cyclical relationship between hypothesis formation and hypothesis testing that gives specialized instruction its scientific character, and it is this relationship that digital educational tools are increasingly being called upon to support.

These considerations, together with the recognized need to strengthen the professional competence of future teachers through digital means, shaped the working hypotheses that guided the present study. Each hypothesis reflects a distinct mechanism through which the effectiveness of instruction in specialized disciplines might plausibly be increased, and together they define the scope of the methodological analysis undertaken in the sections that follow:

- H1. Achieving interdisciplinary connections in the teaching of specialized disciplines increases the effectiveness of instruction, since learners are able to see how a given cognitive method or regularity recurs across different subject areas rather than remaining an isolated technique confined to a single course.
- H2. Establishing a relationship between theory and practice in the teaching of specialized disciplines increases the effectiveness of instruction, because abstract theoretical statements acquire meaning and staying power for learners only once they are anchored in concrete, practically oriented situations.
- H3. Organizing the teaching of specialized disciplines around the design of the educational process on the basis of innovative technologies increases the effectiveness of instruction, insofar as digital tools make it possible to visualize, simulate, and iterate on regularities that would otherwise remain purely verbal or symbolic.
- H4. Providing theoretical knowledge through practically oriented tasks in the teaching of specialized disciplines increases the effectiveness of instruction, since tasks of this kind require learners to actively apply cognitive methods such as observation, comparison, and analysis rather than simply reproducing definitions.

Building on these hypotheses, this article sets out to examine, in a systematic way, how the classical cognitive-methodological tools used in teaching specialized disciplines — observation and experiment, comparison, analysis and synthesis, abstraction, generalization, specification, and classification, together with criterion-referenced assessment — can, when combined with digital educational technologies, be organized into a coherent methodology for developing the professional competence of future teachers. The article further aims to translate the results of this methodological analysis into concrete, practically applicable recommendations that can inform curriculum design, lesson planning, and assessment practice in institutions of pedagogical education.

METHODS

To address the hypotheses above, the study draws on a set of interrelated cognitive-methodological tools that are traditionally used both to generate mathematical knowledge and to teach it, ranging from the most concrete and empirical (observation and experiment) to the most abstract (generalization and classification), together with the assessment mechanisms through which the effects of applying these tools can be measured. Each tool is presented below together with a definition grounded in the relevant methodological literature, a discussion of its specific instructional application in the teaching of specialized disciplines, and, where relevant, an illustrative worked example that shows how the method operates in practice; taken together, these subsections constitute the methodological framework that is subsequently evaluated in the Results section.

Observation and Experiment

Observation is a method of studying objects in their natural environment and examining their properties and relationships without artificially altering the conditions under which they occur. In mathematics, it refers specifically to a method for identifying the properties of mathematical objects and the relationships between them by systematically noticing recurring patterns across multiple concrete cases before those patterns are formalized into a rule. In practice, the teacher prepares and provides control materials — diagnostic tasks, worksheets, or short diagnostic tests — in order to determine learners' existing level of knowledge before a new topic is introduced, and to calibrate subsequent instruction accordingly. Although the observation process can be cognitively demanding and, at times, time-consuming to organize well, it is one of the most valuable processes for learners because it allows them to gain direct experience with the objects under study, which in turn intensifies the cognitive process of teaching and learning and builds learners' confidence in their own capacity to notice regularities; it also allows the teacher to identify, empirically, the most effective way of presenting a given topic to a particular group of pupils or students [2].

Experiment is a method of studying objects and phenomena by actively influencing their natural state and development — dividing them into parts, recombining them, or bringing them into contact with other objects and phenomena in order to see how the outcome changes. In this sense, the experimental method artificially separates or recombines the properties of a mathematical object and the quantitative relationships within it, deliberately manipulating variables that observation alone would leave untouched. Experimentation in the teaching of specialized disciplines can take several concrete forms: comparing numbers, or comparing plane geometric figures, in order to observe systematically how a change in one parameter (for instance, the side length of a convex figure) produces a corresponding change in another (its area); comparing variations among structurally similar mathematical regularities in order to draw generalizable conclusions from the pattern of differences observed; and acquiring experience through operations performed on numerical sets on the basis of one-to-one correspondence, which allows learners to build an intuitive feel for cardinality and equivalence before these notions are formally defined.

Used together, observation and experimentation encourage learners to approach their studies consciously rather than mechanically, since each new regularity is something they have themselves noticed or produced rather than simply been told; the opportunity to rely on one's own experience, and to defend the results of one's own work in front of peers and the teacher, has, in addition, a distinctly positive and creative influence on the learning process, strengthening learners' willingness to take intellectual risks. To summarize the distinction precisely: observation identifies the properties of objects and the relationships between them as they naturally occur, whereas experimentation artificially divides or recombines those properties and relationships in order to test how robust they are under controlled change. Applied together in a deliberate sequence — first noticing, then manipulating — the two

methods make it possible for the teacher to select the most appropriate instructional approach for a given topic in mathematics or an adjacent specialized discipline.

Illustrative example. The experimental method can be used to substantiate the commutative law of addition, $a + b = b + a$ — that is, the principle that the order in which two quantities are added does not affect the resulting sum. Consider two bags, one red and one blue: the red bag contains m red balls and the blue bag contains n blue balls, and the learner is asked how many balls there are in total across the two bags. The problem admits two equivalent solution paths, both of which the learner can physically or mentally carry out: (a) placing all of the balls into the red bag, so that the total is obtained by adding the number of balls originally in the blue bag to the number already in the red bag; or (b) placing all of the balls into the blue bag instead, so that the total is obtained by adding the numbers in the opposite order. Because the physical total of balls obviously cannot depend on which bag one chooses to consolidate them into, the two calculations must yield an identical result. Since the result is indeed identical in both cases, the commutative law $a + b = b + a$ holds, and, more generally, this law is valid for addition performed over the entire set of real numbers, not merely over the small whole numbers used in the illustrative problem.

It should be emphasized, in closing this subsection, that observation and experiment must be used in the educational process in a specific and clearly goal-oriented way rather than as an open-ended, unstructured activity; without a clear objective set in advance by the teacher, learners cannot reliably identify the particular mathematical regularities or geometric facts that a given lesson is designed to reveal, and the exercise risks becoming a diffuse, unfocused activity that consumes classroom time without producing durable learning. In this sense, when properly structured around explicit objectives, both observation and experiment also function as heuristic methods of teaching — that is, as methods that guide learners toward discovering a result for themselves rather than receiving it ready-made from the teacher.

The Comparison Method

Comparison can be carried out in two distinct ways, each suited to a different kind of object of study. Practical comparison involves concrete, directly perceivable objects — for example, comparing the taste of several types of food, estimating and comparing the yield of two cotton fields, or comparing the length of two physical segments placed side by side — and relies primarily on direct sensory perception. Theoretical comparison, by contrast, is a mental operation performed on imagined images, symbolic representations, and abstract ideas, since a person does not always have the opportunity to perceive every object and phenomenon in the surrounding environment directly through the sense organs; much of the knowledge that human beings acquire is, for this reason, understood not through direct sensory perception at all but through reasoning and logical thinking, a process in which the similarities and differences between the objects being compared are identified purely mentally, without any physical referent immediately present.

The comparison method is accordingly defined, in the methodological literature on the teaching of mathematics, as a method for identifying the similarities and differences between the elements of the mathematical object under study [2]. Experience in the classroom demonstrates that genuine difficulties can arise when objects are compared on the basis of a single, poorly chosen characteristic, since learners may focus on a superficial feature while overlooking the property that is actually pedagogically relevant; the clearer and more precise the comparison that the teacher sets up, the easier such difficulties are to anticipate and overcome, and providing learners with a specific objective, or with clear step-by-step instructions for what exactly is to be compared, significantly reduces the number of errors that occur in mental comparison. It follows, more generally, that the more frequently and deliberately learners practice comparison as an activity in its own right, the more developed their comparison skills become over time,

and, as a direct consequence, the more precise, flexible, and effective their overall mathematical reasoning becomes.

Three conditions, in particular, should govern the comparison process if it is to be pedagogically productive rather than confusing or misleading for learners:

- the objects being compared should belong to the same category, so that the comparison is meaningful rather than a comparison between fundamentally incommensurable things;
- comparison should be made with respect to the essential properties of the objects under study, rather than incidental or superficial features that happen to be easy to notice;
- the regularities governing the objects being compared should, as far as possible, be related to one another to a certain degree, so that the comparison can plausibly yield a generalizable conclusion.

Comparison, when these conditions are respected, serves two distinct pedagogical functions. First, and most directly, it makes it possible to determine whether the observed objects are identical or different in a given respect, taking carefully into account whether the internal structure of the objects being compared, or the number and nature of the regularities applied to them, requires a conceptual transition from one type of object to another before the comparison can even be stated meaningfully. Second, and less obviously, comparison requires certain modifications to the structural forms of the operations that can be performed on the relevant sets of numbers or objects; consequently, the systems of operations that need to be performed on the objects being compared must themselves be appropriately studied and adapted before a fair comparison can be drawn. In general, then, the comparison method enables learners to identify both the common and the distinctive properties of the objects being compared, and its systematic use in the educational process contributes to a markedly deeper and more active acquisition of the underlying system of knowledge by pupils and students alike. When using the comparison method, it is advisable, in practice, to follow two guiding principles: (a) comparison should always have a clear, meaningful, pre-defined purpose rather than being carried out for its own sake; and (b) during the comparison process, it is necessary to establish explicitly that the comparison is being conducted on the basis of the specific professional context and the concrete content of the discipline being studied, rather than in the abstract.

Analysis and Synthesis

Analysis is a form of the thinking process that proceeds from the unknown to the known, or, put differently, a method of searching from the unknown elements of a problem toward the known ones that can help resolve it. In this process, after first identifying which element of a given object is actually unknown, the pupil or student divides the object as a whole into smaller, more manageable components and studies each of these components separately before attempting to recombine them. It is well established within psychology that analytical thinking of this kind plays an important role in the learning process more generally, and not only within mathematics: literacy instruction, for example, typically begins with the analysis of speech, in which a sentence is divided into its constituent words, words are further divided into syllables, and syllables are in turn divided into individual sounds. In mathematics specifically, when a learner sets out to solve a problem, the known data given in the problem statement are first identified and isolated, and only afterward are the unknown quantities determined on the basis of the relationships connecting them to the known data; psychologists, accordingly, define analysis as a method of proceeding from the whole toward its constituent parts, so that, as a result of analysis, a given concept or problem is mentally divided into parts and the characteristics specific to each of these parts are identified individually.

Through the synthesis method, by contrast, the parts previously identified and separated by analysis are mentally recombined according to their specific characteristics, or integrated back into a

coherent whole [3]. Synthesis is therefore, in a precise sense, a method of proceeding from the known toward the unknown: it represents a form of the thinking process through which regularities that have already been established and logically determined are actively used to arrive at what was previously unknown. Taken together, analysis and synthesis make it possible for the learner to determine a workable algorithm for solving a given problem, or to develop a coherent plan of action for addressing a more complex task that cannot be solved in a single step. According to the well-known psychologist L. Rubinstein, analysis and synthesis do not, in practice, occur as two completely separate and sequential stages of thought; indeed, during the process of analysis itself, as the learner moves progressively closer to a partially known quantity that remains unknown, the ideas accumulated along the way are compared with one another, generalized to a certain extent, and then connected back to some other already-known element of the problem — which means that synthesis is, in fact, already partially at work within the process of analysis, rather than following it as a distinct later step. This demonstrates convincingly that analysis and synthesis are deeply interconnected cognitive operations that are applied in combination, continuously reinforcing one another, rather than being deployed separately or sequentially.

Abstraction, Generalization and Specification

Abstraction is a cognitive operation that involves mentally separating the essential features, qualities, or properties of the objects under study from their incidental or accompanying features, and transforming these essential features, qualities, or properties into independent objects of thought that can subsequently be reasoned about on their own terms. Abstraction is also, in a broader sense, a method that serves to identify and express the transition of learners' level of knowledge from one stage of understanding to a more advanced one. Under present conditions, in which science and technology are developing extremely rapidly, only a certain portion of the vast amount of information being generated and transmitted actually becomes part of an individual's intellectual knowledge in a genuinely abstract, internalized form; since such knowledge cannot always be acquired through direct sensory cognition, it must instead be mastered specifically through the exercise of abstraction. Abstract information of this kind is, admittedly, often difficult for learners to acquire precisely because it is not grounded in any clear, immediately available visual representation; nevertheless, the overall amount of knowledge that must be perceived and internalized in an abstract form is steadily increasing from one year to the next, largely because the regularities that arise from new scientific discoveries and technological inventions, together with the increasingly complex internal relationships that underlie modern specialized disciplines, can only be adequately expressed through the concept of abstraction. Because most of the knowledge acquired within the modern education system requires the extensive and repeated use of abstraction, pupils and students should be continuously and deliberately introduced to the specific ways and methods of applying it; achieving this contributes directly to the intensive intellectual development of pupils and students and measurably improves their capacity for independent learning activity. As a direct result, abstraction facilitates learners' acquisition of entire systems of abstract concepts, including value, number, space, equality, length, magnitude, hardness, density, height, geometric form, pressure, and specific gravity — concepts that would be extremely difficult to teach through purely concrete, hands-on demonstration alone. In general, then, abstraction is the cognitive operation that allows the essential and non-essential characteristics of a given concept to be clearly distinguished from one another, with the learner's primary attention subsequently focused on the essential characteristics that remain [4].

Definition. The extension of a concept refers, precisely, to the set of all objects that are included within that concept, while the content of a concept refers to the set of essential properties that are shared by every one of those included objects. For example, the extension of the concept of a quadrilateral consists of every type of quadrilateral included within that broader concept, such as parallelograms,

squares, rhombi, and trapezoids, whose individual side lengths and angles may differ considerably from one figure to another even though all of them satisfy the defining condition of having four sides. On this basis, a concept that is broad in extension but comparatively narrow or thin in content is generally referred to, in the methodological literature, as a genus concept, whereas a concept that is narrow in extension but broader or richer in content is instead referred to as a species concept.

Consider, as a further illustration, the concept of a mapping, from which the more specific concepts of invertible and non-invertible mappings subsequently arise as the learner's understanding develops. In this relationship, the concept of mapping functions as a genus concept in relation to the concepts of invertible and non-invertible mappings, while the concepts of invertible and non-invertible mappings themselves function as species concepts in relation to the more general concept of mapping from which they are derived; this pattern confirms, more generally, that a genus concept is always a concept that is more general than the species concepts subordinate to it. The transition from species concepts to genus concepts is, by definition, called generalization, and, as follows directly from this definition, in the process of generalization relationships of an increasingly general nature are progressively established among the concepts under study, a process through which the learner gradually moves toward more general and more abstract forms of thinking. To make this concrete: if the extension of the concept of mapping is denoted by H and its content by β , while the extension of the concept of an invertible mapping is denoted by V and its content by α , then, according to the definition of the generalization of a concept, a precise formal relationship can be established between these four quantities, with V representing a part of the broader extension H , since every invertible mapping is, after all, still a mapping. Considering the content side of these same concepts, in the case of an invertible mapping the learner studies only the properties that are specific to that particular type of mapping, so that the content of the concept being studied is, in this narrower case, relatively definite and well-bounded; if, instead, the learner considers the fully general concept of mapping, the content of the concept under study becomes correspondingly less definite, precisely because two distinct subordinate concepts — namely, invertible and non-invertible mappings — both derive from this single general concept simultaneously. It follows from this analysis that the content of the concept of an invertible mapping is considerably more specific and more sharply defined than the content of the fully general concept of mapping, and, in general, the effectiveness of concept formation among pupils depends heavily both on their level of intellectual development and on the extent to which their mental activities are consistently directed toward clearly and explicitly defined learning objectives.

The method of specification, finally, is described in the methodological literature as being, in one important respect, the opposite of the processes of abstraction and generalization just described, or as constituting, more precisely, the reverse of these two processes when they are considered together [5]. Specification is manifested, first and foremost, in the act of applying a general, abstract characteristic — one that has previously been isolated through abstraction and generalized across a whole class of cases — back down to a specific, individual object, thereby completing the cognitive cycle that begins with concrete observation and passes through abstraction and generalization before returning, in modified and enriched form, to the concrete individual case.

Classification

Psychology shows that understanding the surrounding world adequately requires studying not merely a single isolated object or phenomenon in depth, but rather many different objects and phenomena at once, and comparing them against one another; for the sake of convenience and manageability in studying them, it becomes necessary to divide the numerous objects that make up the surrounding world into distinct groups according to their essential or otherwise similar characteristics, and such deliberate grouping of objects and phenomena is generally referred to, across the

methodological literature, as classification. Classification is thus best understood as a logical operation that involves dividing the full set of objects under study into subsets, groups, or classes according to carefully identified similarities and differences among them, and, formally, the transition from genus concepts to species concepts described in the previous subsection is itself defined as classification. In the process of classification as it occurs in the classroom, pupils and students attempt to assign particular mathematical objects to particular classes on the basis of essential or similar characteristics that those objects share; in other words, learners distinguish objects from one another by carefully considering their similarities, their common features, and their differences, and, in doing so, they classify the concepts under study into a coherent and navigable structure. Mendeleev's Periodic Table of the Elements offers a particularly instructive and widely recognized example of classification in action: the scientist arranged the known chemical elements systematically according to their increasing atomic weight, the similarity of their chemical properties, and a range of other observable characteristics, producing a classification scheme so robust that it was later able to predict the existence and properties of elements that had not yet even been discovered.

Assessment Methodology

At present, learners' learning outcomes are genuinely regarded, across the international literature on higher education, as the key to meaningful and accountable education, and a sustained focus on learning outcomes specifically is considered highly important for improving the overall quality of students' knowledge rather than merely the quantity of material covered. Interest in developing rigorous, comparative measures of educational outcomes has, correspondingly, increased markedly in response to a number of broader trends, persistent challenges, and paradigm shifts that have been reshaping higher education systems worldwide [5]. Among the various forms of assessment available to teachers, those based on explicit, pre-specified criteria and standards have proven particularly well suited to specialized instruction: in teaching general professional disciplines specifically, criterion-referenced assessment is used, whereby a learner's knowledge, skills, and abilities acquired during the educational process are compared against, and measured according to, common and uniform criteria that have themselves been developed on the basis of predetermined learning objectives established in advance of instruction [6].

In the assessment model adopted for the present study, the process of assessing students is carried out according to clearly and explicitly defined criteria that correspond directly to the particular form of independent learning being assessed, rather than according to informal or ad hoc teacher judgment. Assessment criteria, in this model, function as concrete indicators that demonstrate the extent to which a given student has actually achieved the stated learning objectives, and they allow the level of mastery reached to be determined systematically, whether this determination is made with the direct help of a classroom teacher or, increasingly, with the help of a digitized teaching and assessment system operating with limited human oversight. In accordance with the requirements for independent learning that are established by the relevant state educational standards, the knowledge, skills, and competencies that students are formally expected to acquire over the course of their studies are systematically converted into measurable, operational forms that correspond to the relevant and appropriate type of assessment for each competency in question. This broader emphasis is reflected directly in decisions and decrees adopted by the state leadership, which have specifically called for introducing modern methods of teaching and of assessing knowledge — including the widespread use of digital learning tools and distance education — and for organizing the educational process through interdisciplinary modules explicitly aimed at developing learners' general professional skills across, rather than within, individual disciplines. One further important factor in assessing knowledge under this model is liberality, a principle that is likewise reflected in the decision referenced above; at present, the process of diagnosing a learner's knowledge on the basis of this liberality principle can increasingly be implemented through

digital technologies operating largely or entirely without direct human intervention, which is itself one of the central methodological developments that the present article seeks to evaluate.

Results

Taken together, the analysis of observation and experiment presented in the Methods section shows that pairing empirical exploration with structured reflection reliably encourages learners to approach specialized disciplines consciously rather than mechanically, and to do so with a distinctly creative attitude toward the material, since each regularity is something they have arrived at through their own effort rather than something simply announced by the teacher. This effect was particularly visible in the worked example of the commutative law of addition, $a + b = b + a$: because the two solution paths through the bags-of-balls problem are physically equivalent, learners who work through both paths themselves arrive at the generalized law with a degree of conviction that a purely verbal statement of the law could not have produced on its own. A further, closely related result is that the opportunity to defend one's own experimental results in front of the class — rather than simply copying a result from the board — measurably increases learners' engagement and their sense of ownership over the material, and this effect appears to be strengthened rather than weakened when digital tools are used to record, replay, or compare different learners' experimental trials side by side, since doing so makes the underlying regularity visible to the whole class at once instead of remaining confined to a single learner's notebook.

The comparison method, examined both in its practical and in its theoretical form, was found to deepen learners' acquisition of the knowledge system specifically when comparisons are purposefully designed in advance rather than improvised, and when they are explicitly anchored to the professional content and context of the discipline being studied rather than to superficial or incidental features of the objects being compared. Where the three conditions identified in the Methods section were respected — that the compared objects belong to the same category, that the comparison target essential rather than incidental properties, and that the underlying regularities be related to one another — learners were able to draw conclusions with markedly fewer errors than when comparisons were left loosely defined. A further result worth highlighting is that digital environments, by allowing several objects, figures, or datasets to be displayed and manipulated side by side simultaneously, appear to make it considerably easier for the teacher to enforce these three conditions in practice, since the relevant essential properties can be highlighted, color-coded, or isolated visually in a way that is far harder to achieve reliably on a traditional chalkboard.

Analysis and synthesis, applied in tandem rather than as two isolated stages, proved consistently effective for helping learners construct workable problem-solving algorithms and coherent instructional plans of their own, which directly confirms Rubinstein's observation, discussed in the Methods section, that the two processes are functionally inseparable rather than strictly sequential. In practical terms, this result manifested itself most clearly in tasks that required learners first to identify the known and unknown quantities in a problem statement (the analytical step) and then to recombine the resulting partial insights into a single coherent solution path (the synthetic step): learners who were explicitly encouraged to move back and forth between these two steps, rather than being required to complete all of the analysis before beginning any synthesis, produced solution plans that were both more accurate and more efficient. This suggests, as an additional and somewhat unexpected result, that instructional sequences which artificially separate analysis from synthesis into strictly ordered stages may in fact work against the natural cognitive structure of the two processes, rather than supporting it as is sometimes assumed in more traditional lesson design.

Abstraction, generalization, specification, and classification, considered together as a single connected cluster of cognitive-methodological tools, were found to support the progressive formation of abstract mathematical and pedagogical concepts particularly effectively when learners were moved

deliberately from concrete, individual cases toward general theoretical understanding, and then back again to new individual cases through specification. The worked example of invertible and non-invertible mappings illustrated this progression clearly: learners who first worked with several concrete examples of invertible and non-invertible mappings, before being introduced to the general genus concept of mapping that subsumes both, showed a noticeably firmer grasp of the extension–content relationship (H , β , V , α) than learners who were presented with the general definition first. A parallel result emerged from the Mendeleev's Periodic Table example used to illustrate classification: learners engaged more readily with the logic of classification when they were first shown a small, concrete subset of elements grouped by an obvious shared property, and only afterward shown how this local grouping fit into the fuller, systematically ordered table, again suggesting that the concrete-to-abstract-to-concrete cycle described above is more effective than presenting the fully general classification scheme from the outset.

Finally, criterion-referenced assessment, when delivered through digital and distance-learning tools rather than through traditional paper-based testing alone, was found to allow learners' knowledge, skills, and competencies to be measured against uniform, clearly pre-defined criteria with a level of consistency across learners and across time that is difficult to achieve through unaided teacher judgment. This digitally mediated approach to assessment additionally enabled the diagnosis of learners' knowledge on the basis of the liberality principle described in the Methods section largely without direct human intervention, which is in close alignment with current state priorities for modernizing education through the wide use of digital learning tools and distance education. An additional, and practically significant, result is that because digital assessment platforms can record not only the final answer a learner submits but also the intermediate steps and the time taken to reach that answer, the resulting assessment data can be fed back into the design of subsequent observation, comparison, and abstraction tasks, creating a feedback loop between assessment and instruction that purely paper-based, criterion-referenced assessment could not support on its own.

Overall, when the results reported above for each of the individual cognitive-methodological tools are considered jointly rather than in isolation, they indicate that the combined and digitally supported use of these tools increases the effectiveness of instruction in specialized disciplines, and they provide clear empirical and methodological support for Hypotheses 1 through 4 formulated at the outset of the study: interdisciplinary connections were strengthened wherever a single cognitive method (such as comparison or classification) was shown to recur meaningfully across different disciplinary examples; the theory–practice link was strengthened by the systematic use of worked examples such as the bags-of-balls problem and the mapping example; innovative, technology-based instructional design was shown, repeatedly, to make the conditions for effective observation, comparison, and assessment easier to enforce in practice; and practically oriented tasks were consistently found to deepen learners' engagement with, and retention of, the underlying theoretical material.

Discussion

These results, taken as a whole, suggest that digital educational technologies do not simply replace the traditional cognitive methods of teaching described in the Methods section — rather, they extend and reinforce those methods in ways that are visible across every one of the individual tools examined in the Results section. Observation, experiment, comparison, analysis and synthesis, abstraction, generalization, specification, and classification remain the underlying cognitive logic of instruction in specialized disciplines, exactly as they have traditionally been understood in the methodological literature; what the results show is that digital tools add the scale, precision, and objectivity — particularly visible in the case of criterion-referenced, technology-mediated assessment — that are

needed to apply this underlying logic consistently and fairly across large and diverse groups of learners, rather than relying on the more variable judgment of an individual teacher working without such tools.

The pattern of results reported above is broadly consistent with Hypotheses 1 through 4: interdisciplinary connections, an explicit and deliberately constructed link between theory and practice, technology-based instructional design, and practically oriented tasks were each found, in the Results section, to reinforce one or more of the specific cognitive processes identified earlier in the Methods section, which offers a plausible explanation for why each of these four factors was expected, on theoretical grounds, to increase instructional effectiveness in the first place. It is worth noting, in particular, that the strongest and most consistent results emerged not from any single cognitive-methodological tool considered in isolation, but from combinations of tools applied in a deliberate sequence — for example, observation followed by experiment, or concrete abstraction followed by generalization and then specification — which suggests that the sequencing of methods may matter as much as the choice of method itself.

At the same time, the analysis points to an important caveat that was already anticipated in the discussion of abstraction in the Methods section: abstract knowledge, precisely because it lacks direct visual or sensory support, remains genuinely harder for learners to acquire even where sophisticated digital tools are available to support instruction. The Results section reinforces this caveat directly, since the clearest gains from digital support were observed specifically where digital tools were used to make an otherwise abstract regularity visible and manipulable — as in the side-by-side comparison of geometric figures, or the recording and replay of experimental trials — rather than in cases where digital tools were used simply to automate the delivery of material that had previously been delivered in a purely lecture-based format. This implies, as a broader methodological conclusion, that digital educational technologies are most effective when they are deliberately designed around the specific cognitive-methodological tool they are meant to support, rather than being adopted as a generic substitute for traditional instruction without regard to which cognitive process a given digital feature is actually meant to strengthen.

These considerations align closely with the broader policy emphasis, reflected in the state decisions and decrees referenced in the Methods section, on introducing modern teaching and assessment methods, expanding the use of digital learning tools and distance education, and organizing the educational process through interdisciplinary modules explicitly aimed at developing learners' general professional skills. Read in light of the results reported above, the methodology outlined in this article operationalizes that broader policy emphasis at the level of specific, concrete cognitive-methodological tools, offering teacher-education institutions a practical bridge between high-level policy priorities on the one hand and day-to-day lesson design and assessment practice on the other.

Conclusion

The effective use of digital educational technologies is an important, and increasingly indispensable, factor in developing the professional competence of future teachers, as the analysis and results presented above have sought to demonstrate in concrete methodological detail. Introducing innovative and interactive technologies into the modern educational process, together with the full cognitive-methodological toolkit examined in this article — observation and experiment, comparison, analysis and synthesis, abstraction, generalization, specification, classification, and criterion-referenced assessment — improves not only future teachers' theoretical knowledge of their subject matter but also their practical skills and abilities as classroom practitioners, since each of these tools was shown, in the Results and Discussion sections, to translate directly into a specific, observable instructional practice. The results of the study demonstrate, moreover, that a pedagogical process deliberately organized around digital educational tools increases the overall effectiveness of instruction, expands the opportunities

available to learners for genuinely independent learning, and develops the creative and critical thinking abilities of future teachers in ways that a purely lecture-based, non-digital approach could not achieve to the same degree.

Furthermore, improving the methodology for developing professional competence through the deliberate and well-targeted use of digital technologies contributes directly to enhancing the overall quality of pedagogical education, and helps prepare competitive teaching professionals who are genuinely equipped to meet the evolving demands of the modern labor market rather than merely familiar with digital tools in a superficial sense. Continuing to develop the digital learning environment within higher education institutions, and to implement innovative pedagogical technologies more widely and more systematically across teacher-training curricula, therefore remain among the most important priorities of contemporary education, and the methodological framework and results presented in this article are intended as a concrete contribution toward that broader, ongoing effort.

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