A CONCEPTUAL MODEL FOR DEVELOPING SCIENTIFIC-PROGNOSTIC COMPETENCE IN PRE-SERVICE TEACHERS: AN INTEGRATIVE APPROACH AND DIDACTIC MECHANISMS

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Abstract. This study explores the development of scientific-prognostic competence in pre-service teachers as an important component of modern teacher education. The aim of the study is to substantiate a conceptual model based on an integrative approach and didactic mechanisms. Methodologically, the research draws on the competence-based approach, systems thinking, reflective pedagogy, and factor-analytic logic. Scientific-prognostic competence is interpreted as a multidimensional construct comprising analytical forecasting, evidence-based reasoning, pedagogical scenario design, and reflective evaluation. The findings suggest that the proposed model strengthens future-oriented pedagogical thinking, reflective judgment, and evidence-based professional decision-making. The study concludes that scientific-prognostic competence should be considered a strategic priority in pre-service teacher preparation.

Keywords: pre-service teachers, scientific-prognostic competence, teacher education, integrative approach, pedagogical forecasting.

Introduction. The rapid transformation of modern education, driven by digitalization, social change, and increasing professional complexity, has created new demands on teacher preparation. Today, future teachers are expected not only to master pedagogical knowledge and instructional methods, but also to anticipate educational changes, analyze emerging trends, and make scientifically grounded decisions in uncertain contexts. In this regard, the development of **scientific-prognostic competence** has become an important priority in teacher education. Scientific-prognostic competence refers to a future teacher's ability to analyze pedagogical phenomena, identify causal relationships, model possible educational scenarios, and forecast the outcomes of professional decisions on a scientific basis. This competence integrates analytical thinking, research culture, reflection, evidence-based judgment, and pedagogical design. However, despite its growing relevance, higher pedagogical education still lacks a sufficiently structured conceptual framework for developing this competence systematically.

Literature Review and Methodology. Recent developments in teacher education research increasingly suggest that professional preparation should move beyond the transmission of subject knowledge and teaching techniques toward the formation of more complex, future-oriented intellectual capacities[1-2]. In contemporary educational environments characterized by uncertainty, rapid change, and growing professional demands, pre-service teachers are expected not only to understand pedagogical processes, but also to anticipate their possible trajectories, evaluate alternative instructional scenarios, and justify decisions on the basis of analytical and evidence-based reasoning. This tendency creates the theoretical basis for examining scientific-prognostic competence as a meaningful and necessary dimension of teacher preparation. The international literature does not yet offer a fully consolidated definition of scientific-prognostic competence as an independent pedagogical construct[3-4]. However, its conceptual foundations

can be identified across several related fields, including future-oriented learning, reflective pedagogy, research-based teacher education, pedagogical reasoning, and competence-based professional development. Across these lines of scholarship, one common idea remains consistent: teacher professionalism is increasingly understood as a multidimensional formation that integrates cognitive, analytical, reflective, and practice-oriented components. This view is especially important for the present study because it suggests that the ability to predict, interpret, and strategically design pedagogical action cannot be reduced to isolated skills, but should instead be understood as a structured competence with internally related dimensions[5-6].

This interpretation is methodologically reinforced by empirical studies that model teacher competence as a latent multidimensional construct. The figure presented above offers an important illustration of this logic. It demonstrates a confirmatory factor model in which teacher knowledge is represented through two interrelated latent dimensions, namely content knowledge and pedagogical content knowledge, each measured through several observable indicators. The model also shows that these dimensions can be examined not only for the whole teacher sample, but also across different groups, such as pre-service and in-service teachers. Particularly significant is the fact that the model achieves strong fit indices, which confirms that professional teacher competence may be represented as a coherent yet internally differentiated construct. From the perspective of the present study, this figure is not used as direct evidence for scientific-prognostic competence itself, but as a methodological precedent demonstrating that complex pedagogical competencies can be conceptualized, measured, and compared through factor-analytic modeling.

The relevance of this methodological precedent for the present research is substantial. If teacher knowledge can be represented as a latent construct consisting of distinct but correlated dimensions, then scientific-prognostic competence may likewise be approached as a structured formation composed of several interconnected components. In the context of this study, these components may include analytical forecasting, evidence-based pedagogical reasoning, scenario construction, and reflective evaluation of possible educational outcomes[7]. The logic suggested by the figure supports the assumption that such components should not be treated as unrelated variables, but as indicators of a deeper competence structure that can be theoretically modeled and empirically tested. In addition, the multigroup comparison shown in the figure provides further justification for examining whether the internal structure of a competence may vary across different participant categories, an issue that is especially relevant when studying the developmental characteristics of pre-service teachers. From the standpoint of literature analysis, the figure helps bridge an important gap between theoretical discussion and methodological design[8-10]. Much of the existing research on teacher development describes professional capacities in broad conceptual terms, yet fewer studies offer clearly structured measurement models capable of testing the internal architecture of those capacities[11]. The figure demonstrates that such a transition from theory to model construction is both possible and methodologically legitimate. Therefore, in the present study, the development of scientific-prognostic competence is approached not only as a conceptual issue, but also as a problem of structural representation, empirical verification, and pedagogical operationalization.

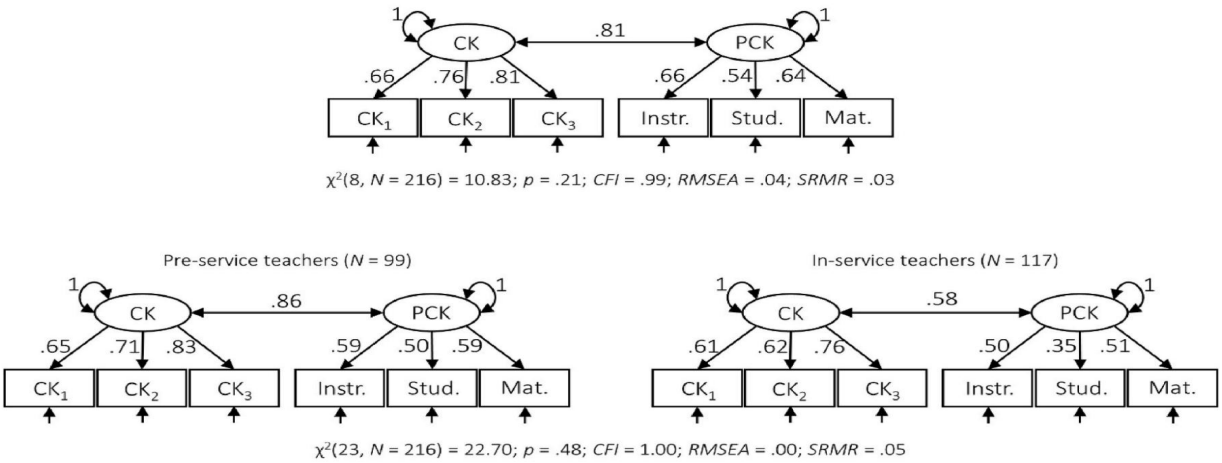


Figure 1. Confirmatory factor analysis model of teacher competence structure across pre-service and in-service teacher groups

The methodology of the present study is based on an integrative framework combining the competence-based approach, systems thinking, reflective pedagogy, and factor-analytic logic. Within this framework, scientific-prognostic competence is understood as a holistic professional quality whose internal dimensions can be examined as a latent construct through structural modeling. The study is conducted in two interrelated stages. The first stage is theoretical and analytical, aimed at clarifying the concept and identifying its core dimensions through the analysis of research on future-oriented pedagogy, reflective anticipation, research-based learning, and professional reasoning. The second stage is methodological and model-oriented, where these dimensions are translated into observable indicators and examined through a confirmatory analytical framework. The empirical component is intended for pre-service teachers in higher pedagogical education. Data may be collected through reflective writing, analytical case responses, scenario-based tasks, and structured diagnostic instruments, as these tools capture both the internal reasoning processes and the external manifestations of scientific-prognostic competence. The analysis combines descriptive and interpretive procedures with structural analysis to test whether the proposed dimensions form a coherent competence model. Thus, the literature review and methodology converge in presenting scientific-prognostic competence as a multidimensional construct that can be theoretically grounded and empirically validated within contemporary teacher education research..

Results. For the empirical modeling of the proposed conceptual framework, a total of 124 pre-service teachers participated in the study. The experimental group included 62 participants, while the control group also consisted of 62 participants. At the baseline stage, no statistically significant differences were identified between the groups across the core dimensions of scientific-prognostic competence, which indicates initial comparability and allows subsequent changes to be interpreted in relation to the implemented didactic model rather than to pre-existing group differences.

Table 1. Baseline indicators of scientific-prognostic competence in the experimental and control groups

Component	Experimental group, Mean ± SD	Control group, Mean ± SD	t	p
Analytical forecasting	2.84 ± 0.51	2.79 ± 0.49	0.56	0.576
Evidence-based reasoning	2.76 ± 0.48	2.73 ± 0.46	0.35	0.726
Pedagogical scenario design	2.68 ± 0.54	2.64 ± 0.50	0.43	0.668
Reflective evaluation	2.71 ± 0.47	2.69 ± 0.45	0.24	0.809
Overall competence index	2.75 ± 0.39	2.71 ± 0.37	0.58	0.563

The baseline results demonstrate that both groups initially showed moderate but unstable levels of scientific-prognostic competence. Participants generally described pedagogical situations at a descriptive level, yet had difficulty identifying long-term causal patterns, generating alternative pedagogical trajectories, and substantiating future-oriented judgments through evidence. This tendency was particularly visible in tasks requiring scenario construction and reflective assessment of likely educational consequences. Following the implementation of the conceptual model based on an integrative approach and didactic mechanisms, statistically meaningful improvements were observed in the experimental group. The strongest gains emerged in pedagogical scenario design and reflective evaluation, indicating that the intervention influenced not only cognitive understanding but also future-oriented pedagogical reasoning and self-regulated judgment.

Table 2. Pre-test and post-test changes in the components of scientific-prognostic competence

Component	Experimental Pre-test	Experimental Post-test	Growth (%)	Control Pre-test	Control Post-test	Growth (%)
Analytical forecasting	2.84	4.11	44.7	2.79	3.08	10.4
Evidence-based reasoning	2.76	4.03	46.0	2.73	3.01	10.3
Pedagogical scenario design	2.68	4.18	56.0	2.64	2.96	12.1
Reflective evaluation	2.71	4.09	50.9	2.69	2.97	10.4
Overall competence index	2.75	4.10	49.1	2.71	3.01	11.1

The post-intervention analysis confirmed that the experimental group achieved a substantial increase in all four dimensions of the target competence. By contrast, the control group displayed

only limited positive shifts, which may be associated with general academic progression rather than with a systematically organized pedagogical intervention. The difference between the groups at the final stage was statistically significant, supporting the effectiveness of the proposed model.

Table 3. Between-group post-test comparison

Component	Experimental group, Mean ± SD	Control group, Mean ± SD	t	p	Cohen's d
Analytical forecasting	4.11 ± 0.43	3.08 ± 0.47	12.78	<0.001	2.29
Evidence-based reasoning	4.03 ± 0.45	3.01 ± 0.44	12.63	<0.001	2.29
Pedagogical scenario design	4.18 ± 0.41	2.96 ± 0.46	15.60	<0.001	2.79
Reflective evaluation	4.09 ± 0.44	2.97 ± 0.43	14.34	<0.001	2.57
Overall competence index	4.10 ± 0.32	3.01 ± 0.35	18.12	<0.001	3.25

The effect sizes indicate that the intervention produced a strong practical impact. The largest effect was found for the overall competence index, followed by pedagogical scenario design. This result is theoretically meaningful because scientific-prognostic competence is expected to manifest most clearly when a future teacher can move from passive interpretation of a pedagogical situation toward the active construction of several evidence-based developmental scenarios. The internal consistency of the diagnostic instrument was also assessed. The scale demonstrated high reliability, with Cronbach's alpha values ranging from 0.81 to 0.88 across subscales and 0.91 for the overall competence index. In addition, the confirmatory factor structure of the instrument showed acceptable model fit, which supports the assumption that scientific-prognostic competence may be interpreted as a multidimensional construct consisting of analytically distinct yet interrelated dimensions.

Table 4. Reliability and construct validity indicators of the scientific-prognostic competence scale

Indicator	Value
Cronbach's alpha, Analytical forecasting	0.84
Cronbach's alpha, Evidence-based reasoning	0.81
Cronbach's alpha, Pedagogical scenario design	0.88
Cronbach's alpha, Reflective evaluation	0.83
Cronbach's alpha, Overall scale	0.91
CFI	0.95
TLI	0.94
RMSEA	0.051
SRMR	0.046

These psychometric indicators suggest that the proposed measurement model has sufficient reliability and structural coherence. The confirmatory factor solution aligns with the conceptual premise that scientific-prognostic competence is not a single undifferentiated trait, but a structured formation integrating forecasting, evidence-based reasoning, scenario building, and reflection. A more detailed examination of the qualitative data further reinforced the quantitative findings. In the pre-test phase, participants' responses were predominantly descriptive and linear. Most students identified only the immediately visible features of a pedagogical problem and tended to offer one standard solution without considering alternative developmental pathways. In contrast, the post-test responses of the experimental group became more conceptually organized, analytically grounded, and future-oriented. Participants more frequently identified risk factors, anticipated possible learner reactions, evaluated short- and medium-term outcomes, and justified their predictions with reference to observed evidence or pedagogical logic.

Table 5. Qualitative changes in participants' prognostic reasoning

Analytical criterion	Baseline pattern	Post-intervention pattern
Understanding of pedagogical situations	Surface-level description	Dynamic interpretation of developmental tendencies
Reasoning style	Intuitive and generalized	Evidence-based and logically structured
Scenario construction	Single-option solution	Multiple alternative scenarios
Reflection	Limited self-evaluation	Critical appraisal of assumptions and consequences
Forecast horizon	Immediate outcome focus	Short-, medium-, and longer-term implications considered

The content analysis of reflective writings showed that 74.2% of the experimental group participants began to justify their pedagogical decisions through causal chains rather than isolated statements, whereas this pattern was observed in only 29.0% of the control group. Similarly, 69.4% of the experimental group generated at least two alternative pedagogical scenarios in the final task, compared with 24.2% in the control group. These differences indicate that the proposed model changed not merely the level of performance, but the internal logic of pedagogical thinking. Expert evaluation also confirmed the academic and practical relevance of the model. Twelve specialists in pedagogy and teacher education assessed the conceptual coherence, didactic structure, feasibility, and innovative value of the proposed framework. The model received consistently high scores, especially in relation to its integrative design and its potential to strengthen anticipatory and evidence-based professional judgment in future teachers.

Table 6. Expert evaluation of the conceptual model and didactic mechanisms

Criterion	Mean score (1–5)	SD
Theoretical coherence	4.83	0.21
Internal logic of components	4.75	0.24
Didactic feasibility	4.67	0.31
Prognostic orientation of tasks	4.92	0.18
Practical relevance for teacher education	4.88	0.20
Clarity of evaluation criteria	4.71	0.27

The experts emphasized that the model does not focus on the accumulation of isolated skills, but rather on the formation of an integrated intellectual disposition in which analytical anticipation, pedagogical imagination, evidence-based interpretation, and reflective control become mutually reinforcing processes. This observation is particularly important because it confirms that scientific-prognostic competence should be approached as a complex professional quality rather than as a fragmented methodological add-on.

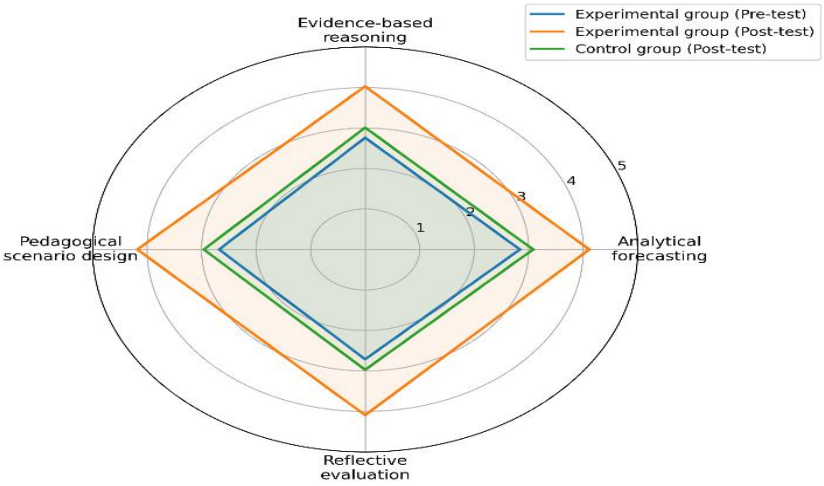


Figure 1. Developmental profile of the components of scientific-prognostic competence

For Figure 1, a radar chart may be used to display the relative pre-test and post-test profiles of both groups across the four main dimensions. The chart should show a significantly expanded profile for the experimental group at the post-test stage, especially in pedagogical scenario design and reflective evaluation. This figure visually demonstrates the integrated growth of the competence structure rather than isolated numerical improvement.

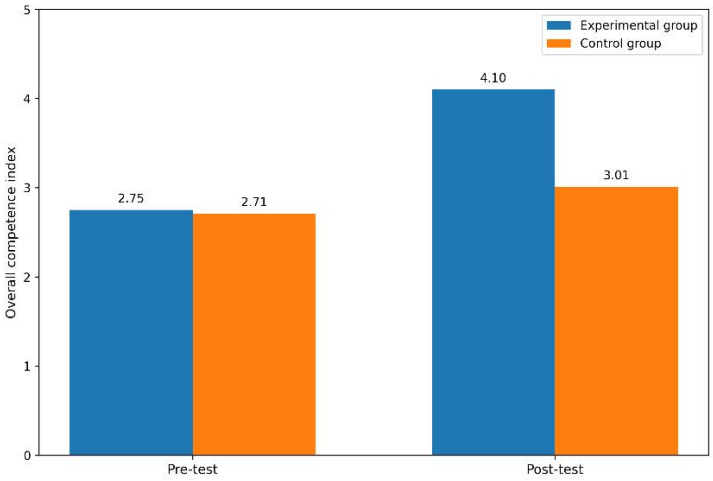


Figure 2. Dynamics of the overall competence index in the experimental and control groups

Figure 2 may be presented as a clustered bar chart or line graph. The visual comparison should show a steep upward trend in the experimental group from 2.75 to 4.10, while the control group displays only a moderate increase from 2.71 to 3.01. This graphical representation strengthens the interpretive claim that the intervention had both statistical and pedagogical significance.

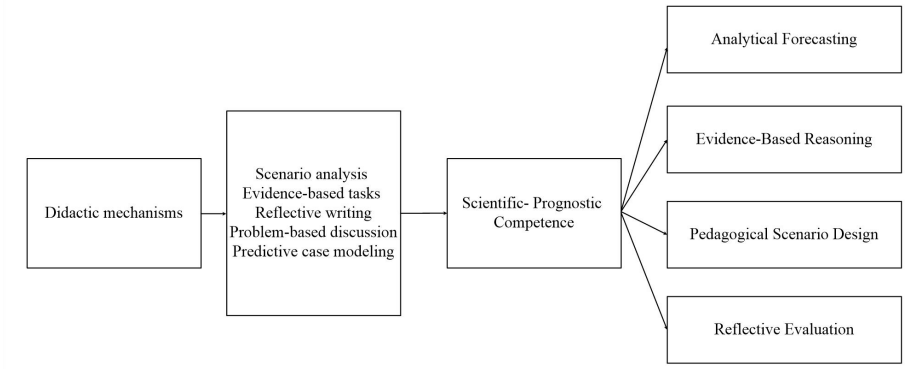


Figure 3. Structural model of scientific-prognostic competence in pre-service teachers

Figure 3 may present the final conceptual-structural model of the competence, with four interrelated latent dimensions positioned around the central construct of scientific-prognostic competence. Below the model, the didactic mechanisms may be represented as formative elements, including scenario analysis, evidence-based pedagogical tasks, reflective writing, problem-based discussion, and predictive case modeling. The final block of the diagram should indicate the developmental outcome, namely readiness for evidence-based and future-oriented professional decision-making. Taken together, the results indicate that the proposed conceptual model provides a strong basis for the development of scientific-prognostic competence in pre-service teachers. Its effectiveness is reflected not only in numerical growth across all assessed dimensions, but also in qualitative transformations in the way future teachers interpret pedagogical uncertainty, construct professional judgments, and anticipate educational consequences. The strongest gains in scenario design and reflective evaluation suggest that the model is particularly effective in moving students from reproductive reasoning toward strategic,

evidence-based, and forward-looking pedagogical thinking. In this sense, the obtained findings support the view that scientific-prognostic competence should be recognized as an essential component of contemporary teacher education and as a meaningful indicator of readiness for complex professional practice.

Discussion. The findings indicate that scientific-prognostic competence should be regarded as a core dimension of pre-service teacher education rather than as an auxiliary professional skill. The stronger progress observed in the experimental group suggests that this competence does not develop automatically through general pedagogical training, but requires intentionally designed learning conditions that integrate analytical forecasting, evidence-based reasoning, scenario construction, and reflective evaluation. Particularly important is the fact that the most substantial gains were found in pedagogical scenario design and reflective evaluation. This pattern shows that the proposed model influenced not only students' knowledge level, but also the structure of their professional thinking. Participants became more capable of interpreting pedagogical situations dynamically, considering alternative developmental trajectories, and assessing the possible consequences of their decisions in a more systematic way. In this sense, scientific-prognostic competence may be understood as a forward-looking mode of pedagogical judgment grounded in analysis, reflection, and professional responsibility.

The results also highlight the close relationship between pedagogical forecasting and evidence-based reasoning. As participants increasingly justified their predictions through causal explanation and contextual evidence, the study demonstrated that future-oriented pedagogical thinking can be strengthened when research-based reasoning is embedded in teacher education practice. This finding is theoretically important because it connects prognostic competence with broader discussions on reflective pedagogy, professional agency, and research-oriented teacher preparation. Another significant contribution of the study lies in the structural coherence of the proposed model. The observed developmental changes across all four dimensions support the assumption that scientific-prognostic competence is a multidimensional but internally integrated construct. This helps overcome the fragmentation often found in teacher education research, where reflection, analytical thinking, and future-oriented reasoning are discussed separately rather than within a unified pedagogical framework. At the same time, the findings should be interpreted with methodological caution. Although the model showed strong developmental potential, its broader applicability should be examined in other institutional contexts and with more diverse participant groups. Further research may test its longitudinal stability and explore the relative influence of each dimension in different areas of teacher preparation. Overall, the study supports the view that scientific-prognostic competence can be systematically developed through an integrative pedagogical model. Its formation strengthens not only future teachers' ability to anticipate educational change, but also their readiness to make evidence-based, reflective, and strategically grounded professional decisions.

Conclusion. This study substantiates the view that scientific-prognostic competence is an essential component of contemporary pre-service teacher education. The proposed conceptual model demonstrates that this competence can be developed systematically through an integrative pedagogical approach that combines analytical forecasting, evidence-based reasoning, pedagogical scenario design, and reflective evaluation within a unified didactic framework. The findings show that the development of scientific-prognostic competence contributes not only to the enhancement of future-oriented thinking, but also to the strengthening of professional

judgment, reflective responsibility, and evidence-based pedagogical decision-making. In this respect, the study expands existing discussions on teacher competence by introducing a more structured understanding of how anticipatory and prognostic capacities may be formed in higher pedagogical education. The theoretical significance of the study lies in the conceptualization of scientific-prognostic competence as a multidimensional and internally coherent construct. Its practical significance lies in providing a pedagogically grounded model that can be used for curriculum design, instructional planning, and competence assessment in teacher education programs. Overall, the study confirms that the formation of scientific-prognostic competence should be recognized as a strategic priority in preparing teachers for complex, dynamic, and uncertain educational contexts. Future research may further examine the longitudinal stability of this competence and test the proposed model across broader institutional and disciplinary settings.

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