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PROCEDURAL KNOWLEDGE IN DEVELOPMENT OF SCIENTIFIC THINKING IN TEACHERS: CERTAIN EXPERIMENTAL SEQUENCES

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This paper analyzes the role of procedural knowledge in the development of scientific thinking and the formation of teaching staff. Procedural knowledge involves skills and procedures, i.e., how we perform certain activities or tasks. Procedural knowledge, in essence, is application-level competences that are related to practical skills and „know-how” in a particular domain. These types of knowledge are essential for the functioning of scientific thinking in complex problem-solving. The article presents the results of a study conducted on a sample of teachers. The study demonstrates that the development-efficiency of scientific thinking among teachers can be facilitated by the exploration of a specially developed training program, focused on the consolidation of declarative knowledge/ competences at the level of knowledge, the systematic involvement of metacognition and the stimulation of procedural competences development at the level of integration.
Keywords: *procedural knowledge, scientific thinking, teaching staff, development.*

CUNOŞTINŢELE PROCEDURALE ÎN DEZVOLTAREA GÂNDIRII ŞTIINŢIFICE LA CADRELE DIDACTICE: UNELE SECVENŢE EXPERIMENTALE

Articolul pune în discuţie rolul cunoştinţelor procedurale în dezvoltarea gândirii ştiinţifice şi în formarea cadrelor didactice. Cunoştinţele procedurale implică abilităţi şi proceduri, adică modalităţile în care realizăm anumite activităţi sau sarcini. Cunoştinţele procedurale, în esenţă, reprezintă competenţele la nivel de aplicare, care sunt legate de aptitudinile practice şi know-how-ul într-un anumit domeniu. Aceste tipuri de cunoştinţe sunt esenţiale pentru funcţionarea gândirii ştiinţifice în rezolvarea problemelor complexe. În articol sunt prezentate rezultatele unui studiu realizat pe un eşantion de cadre didactice. Studiul demonstrează că dezvoltarea-eficientizarea gândirii ştiinţifice la cadrele didactice poate fi facilitată de explorarea unui program formativ special elaborat, axat pe consolidarea cunoştinţelor declarative /competenţe la nivel de cunoaştere, implicarea sistematică a metacogniţiei şi stimularea dezvoltării competenţelor procedurale la nivel de integrare.
Cuvinte-cheie: *cunoştinţe procedurale, gândire ştiinţifică, cadre didactice, dezvoltare.*

Introduction

Procedural knowledge represents one of the three main categories of knowledge, along with declarative and conceptual/theoretical knowledge, addressed by cognitive psychology and cognitive education theory, especially when we approach the development and efficiency of scientific thinking in students and adults (focused on its professionalization) [1]. These categories of knowledge are defining for the understanding and application of information in different fields, including in the professionalization of teaching staff, since they, by carrying out the interconnection *declarative knowledge-procedural knowledge-conceptual knowledge*, ensure the formation-deepening of the human cognitive system, therefore they are the basis of the scientific thinking development [1; 10]. *Procedural knowledge* includes both *problem-solving techniques* and methods, scientific research strategies, and in pedagogical sciences they appear as decisive components of *the architecture and technology of educational process*. The targeted knowledge, in essence, is developed through practical actions (exercising) and direct experience, when it is necessary to solve certain problems of various nature [ibidem].

In the given context, the moment becomes opportune to elucidate the definition of scientific thinking, which we elaborated on the basis of study, analyzes and synthesis carried out on established researches, carried out by the scientists: D. Kuhn [appud 16], R. Raul and L. Elder [13], C. Zimmerman [appud 16], J. Dewey [appud 16], K. Dundar, [appud 13]. E. Joita [7], etc. Thus, *scientific thinking, in our view, represents a higher mental process, intentional and consistent, which manifests itself in complicated/problematic existential situations (socially, personally, educationally, professionally, etc.), which require the utilization of scientific knowledge, cognitive and metacognitive skills; optimal exploration of all operations and forms of thinking within which the person tests hypotheses, heuristic strategies; makes inferences, syntheses, conclusions, predictions and argues pertinently the actions performed.*

Reiterating, we mention that the repetition and application of theoretical knowledge in different real contexts has an essential role in forming, consolidating, but also perfecting procedural knowledge. The role of procedural knowledge in the development of scientific thinking consists in strengthening practical-scientific competences and applicable skills in solving various scientific and existential problems. As previously reported, this type of knowledge is based on theoretical acquisition, valorizing the human experience and repeated practice, and its acquisition includes thoughtful, systemic and systematic practice in various contexts. Therefore, scientific thinking requires a deepening of knowledge, exploration of reflection and accumulation of experience through the application of procedural knowledge. In the given case, compliance with the criterion of scientificity in relation to procedural knowledge represents the defining elements that condition the development of scientific thinking. The targeted process is carried out due to ensuring methodological rigor, paying particular attention to both the theoretical study, conceptualization, as well as the collection, analysis and interpretation of observable and measurable data, which allow the realization of scientific syntheses, conclusions and predictions. Therefore, ensuring methodological rigor cannot be achieved outside of *procedural knowledge* and the exploration of *empirical/experiential nature of the research*, which represents another criterion of scientificity. The scientific approach is based not only on theoretical and experimental investigations, but also on empiricism, that is, on the analysis of experiential plan, of observations, data collected and processed. So, the information comes not only from the theoretical research, the analysis of the accumulated experience and the experimentation carried out in accordance with the object and purpose of the research, but also from the reflection on the side of the investigated matter. Falsifiability, in this context, means that through procedural knowledge, any person, *a subject of scientific thought*, can validate these elements, experimenting, analyzing and objectively interpreting the results obtained and the observations made. Summarizing the foray made, we conclude that scientific research seeks to respect objectivity and neutrality, trying to minimize subjective influences and unargued personal opinions in the process of research and professional activity, emphasizing the role of procedural knowledge.

Certain Theoretical Aspects of Procedural Knowledge

The theory of action, developed by P. Y. Galperin [21], as a component that continues *the theory of cognitive development*, proposed by L. S. Vygotsky [20], focuses on the analysis of relationship between thinking and practical activity, arguing that cognitive development occurs in the context of human actions and activity. L. S. Vygotsky highlighted the importance of social and cultural environment in the cognitive development of individual, emphasizing the role of social interaction and language in the formation of thought. P. Y. Galperin extended this theory by introducing the concept of *action's stages* and emphasizing how individuals learn to think and solve problems through practical activity.

In essence, *action theory* claims that the process of cognitive development is closely related to how a person learns, acts and interacts with the environment, and through practical actions and activities the person *builds, consolidates and validates his/her cognitive and metacognitive knowledge and skills*.

From the perspective of researcher P. Y. Galperin [20], *the mode of action* represents a system of operations that ensures the solving of tasks of a certain type. The mode of action includes the following functional aspects: *of orientation*, which prepares the subject for carrying out the activity; *of execution* and ensures the transformation of the objects of activity; *of control*, which allows checking the correctness of application of the strategies for solving tasks and correlating the products of activity with the desired ones, i.e. with the purpose of activity, which already denotes the presence and activation of the elements of scientific thinking. Thus, the content of learning includes the knowledge intended to be assimilated and the types of actions and activities based on them. Pedagogical experience demonstrates that all the information, processes, actions, instructions of the teaching staff can be well defined, being, in fact, oriented towards the development and exploration of the person's cognitive system, which explicitly contributes to the development and efficiency of scientific thinking. In a neurocognitive aspect, these actions will only constitute an explicit, declarative form of knowledge (competences at the level of knowledge). If they will not be converted and valorized in practice in the form of practiced, realized and consolidated procedural knowledge [5], then, in the knowledge of case and based on the experiential study, with certainty we can mention the fact that the pedagogue does not focus on the development of scientific thinking of students.

From *the perspective of cognitive psychology* [2; 4; 11] and neurodidactics [12], *procedural and declarative knowledge* are mediated by *strategic knowledge*, which controls the latter through the formation and ranking of procedural knowledge [8]. According to the vision of researcher J. R. Anderson [2], *the acquisition of procedural knowledge* occurs when a balance occurs between the detailed procedures that support learning subjects in the specific contexts of solving certain problems and instructive tasks, which are impossible to use without assimilated and realised declarative knowledge. R. McCormick [10], considers that *solving problems* does not necessarily represent a higher order procedural knowledge, but is an element that cannot be neglected in determining the ability *to acquire declarative knowledge in close connection with procedural knowledge* or by prior internalization of a means efficient acquisition of this knowledge. In the given case, the problem of assessment of the procedural knowledge is addressed, but also of their role in the context of assessment of the ability to think scientifically.

The individual's mental processes are conditioned by many factors: intention/goal, context, action, tools, previous experience and interactions with the environment. Thus, the mental activity of generating and solving problems can be carried out separately, but it can also take place simultaneously. Everything will depend on the task the disciple has received. When the task of learning and consolidating efforts to generate and solve problems is placed in the center of attention, then the individual will act, operationally, valorizing on both declarative and procedural knowledge, already acquired. Since it is often difficult to delimit procedural knowledge from declarative ones, including meta-knowledge, in the educational process we operate with objectives versus competences at the level of knowledge, at the level of application and at the level of integration [6], which ensures the elaboration and the effective utilization of didactic design and of course the achievement of concrete results in terms of competence training focused on the development-efficiency of scientific thinking (for students and adults).

As part of the research carried out, the theoretical study allowed us to develop an educational construct, which, from a methodological point of view, would contribute to the development of scientific thinking.

The process of designing and solving problems in neurodidactics [12] is considered as the only way to promote procedural knowledge and appears in many school programs, where various technologies related to each discipline exist and are proposed. From the perspective of cognition, the declarative knowledge, the objects, the tools, *the resolutive strategies* that can be applied, including the process of elaborating - solving problems in the educational framework, interacting with issuing and validating hypotheses, with the valorization of metacognitive skills, in essence, are the basis of the development of thinking scientific [1, 7, 12, 13, 16]. One of the current challenges for teachers is confronting the question of when the subject of scientific thinking, be it a student or a teacher, must pass from creativity, the generation of new ideas to the evaluation of each one or to their selection in accordance with certain criteria (imposed by the concrete discipline, research methodology, etc.). Obviously, declarative knowledge, from the point of view of pedagogy, represents not only the assimilation of information, but implicitly also includes the process of memorization, analysis, synthesis, internalization and formation of the first level of the human cognitive system, which is manifested and externalized through *competences at the level of knowledge* [7]. In this context, the technology of development of the scientific thinking is outlined, starting from the perspective of *cognitive education theory*, which correlates with *the optimizing principles and epistemological conditions of neurodidactics* [12, p. 20-22] by expanding and deepening the four levels of the human cognitive system [apud 7], also taking into account the efficiency of two directions: *scientific education vs education for science and the systematic exercise of creativity and metacognition*. The latter, in the view of I. Neacşu, also emphasizes complementarity at the level of problem-solving, when the subject of scientific thinking uses systematization, combinatorics and communication, thus activating the left hemisphere [12]. These skills, materialized in the form of *procedural knowledge*, serve teachers as methodological support for the development of scientific thinking in students. Both directions can be exploited by teachers by exploring *the Theory of Inventive Problem Solving – TIPS*, developed by G. Altshuller [19], the essential algorithm of which is a complex program, structured and focused on compliance with the legalities of development of the technical systems and designed to analyze and solve inventive problems. This is where the operations of identifying and resolving contradictions, analyzing the initial situation and choosing or developing a strategy for solving a problem are valorized; synthesizing methods, means, including ways to find and apply the most effective solutions to various types of problems; accumulating and processing the best solutions, generalizing and optimizing them to explore them in solving other problems.

As for the development of metacognition, then we mention the fact that we will focus on consolidating and perfecting *both of its constituent components*, that is, *metacognitive knowledge* (declarative knowledge) and *metacognitive skills* (procedural knowledge). Valorizing these two directions of educational technological intervention would allow the full use of procedural knowledge with significant contributions to the further development of scientific thinking.

The purpose of this article is not to put procedural knowledge in the foreground in the development of scientific thinking or to expose its development algorithm, but to nuance their role in the development of scientific thinking in teachers and the possibility of their exploitation in the educational system through the prism of development of the scientific thinking in students.

Next, we propose for analysis the research of involvement of the procedural knowledge within a complex pedagogical experiment, which targeted several aspects regarding the development of scientific thinking among teachers.

All these aspects and sides of knowledge are nothing but a facilitation of scientific knowledge that is mediated by scientific thinking and helps teachers to be more effective in their professional activity [16].

The purpose of this article is not to put procedural knowledge in the foreground in the development of scientific thinking or to expose their development algorithm, but to nuance their role in making the scientific thinking of teachers more efficient and the possibility of exploiting procedural knowledge in the educational system through in terms of the development of scientific thinking in students. Next, we propose for analysis a sequence of the research carried out regarding the involvement of procedural knowledge within a complex pedagogical experiment, which aimed at several aspects regarding the development of scientific thinking among teachers.

Research Methodology

This study shows how teachers' procedural knowledge can contribute to the development of scientific thinking and the transfer of these cognitive skills to students.

The purpose of research lies in the experimental verification of the contribution of procedural knowledge in the development of scientific thinking among teachers.

Research hypothesis: The development and efficiency of scientific thinking in teaching staff can be facilitated by the exploitation of procedural knowledge.

Research sample: The study involved a sample of 288 subjects, teachers from Romania and the Republic of Moldova. Of these, 62 come from rural areas, and 226 from urban areas, representing various levels of education, including primary, secondary and high school. The teachers cover a wide range of subjects, including foreign languages, Romanian, chemistry, biology, psychology, history, geography, mathematics, physics, computer science, physical education and others. (In particular, 139 subjects are from Romania, and 149 are from the Republic of Moldova).

For the data collection, we used a *questionnaire-application to evaluate the scientific thinking of teachers*. The third part of the questionnaire, which refers to procedural knowledge, included a rating scale from 1 to 5, evaluated by experts using the Delphi method [9]. This method provides answers with intermediate options, and in this case, we applied a rating framework *with five options: unsatisfactory, poor, sufficient,* *good, very good*. This approach allows for more subtle nuances to be captured than a simple binary answer (yes/no), which makes the Delphi method effective in data collection in the field of psychopedagogical research. Teacher evaluation focused on specific descriptors and was conducted using the expert evaluation method. 5 experts participated in this evaluation, who were familiar with the answers based on the descriptors presented by the researcher A. Afanas [apud 18, p. 92], to ensure the reliability of data. The evaluation method by means of the valuation of experts is a technique for obtaining additional results from a group of experts versed in the researched issue. This contributes to the formalization of procedures for collecting, summarizing and analyzing the opinions of specialists-experts, transforming them into the most appropriate and efficient form for making an informed decision [23].

In this vein, we make a clarification that expert evaluations can be used at any stage of the study: in determining the purpose and objectives of the study itself, in building and testing hypotheses, in identifying problematic situations, in the course of interpreting any processes, events or facts, to justify the nature of using certain tools in the process of developing recommendations, etc. *Expert evaluation methods are used in situations where the choice, justification and evaluation of decisions cannot be made only on the basis of precise calculations* [ibidem]. We reiterate that the Expert method is a valuable technique for obtaining and comparing qualitative opinions and assessments from a group of experts. By using this method, one can benefit from the expertise and specialized knowledge of practitioners in the field to address complex issues and make informed decisions [23]. However, the expert method also has some limitations. The process can be time and resource consuming as it may involve repeated data collection and analysis by experts. Also, the results obtained may be influenced by the subjective selection of experts and the way in which the questions or statements in the conducted survey are formulated.

In essence, the application of any research method requires the observance of certain rigors, the application of the respective method is no exception.

So, we investigated the following aspects as follows:

The relevance and logics of answer: aims at the importance of opinions presented, their impact on the development of scientific thinking, understanding the meaning, the ability to analyze, compare, concretize, classify, synthesize, generalize, etc. and think about its scientific content; to order the answer in a logical form, coherent with pertinent arguments.

The depth and originality of answer: demonstrates the capacity for reflection, original judgment and to understand the essence of scientific material; the reference to the appreciation and issuing of value judgments, conceptualizations in relation to the subject in question; the ability to penetrate into the essence of subject addressed.

The significance and correctness of answer aims at the ability to provide logical, correct, valuable answers, by highlighting important ideas and theses; awareness and exploitation of denotative and connotative meaning [15, 16, 17, etc.].

Results and analyses

We performed a complex analysis of the data obtained from the subjects on two main axes consistent with the experimental design. We compared and highlighted the differences between subjects in the control group (CG) and those in the experimental group (EG) in two distinct phases: before and after the experimental intervention (Test and Retest). We also compared subjects in the experimental group (EG) at the two measurement times (Test and Retest) and subjects in the control group (CG) at the same two times.

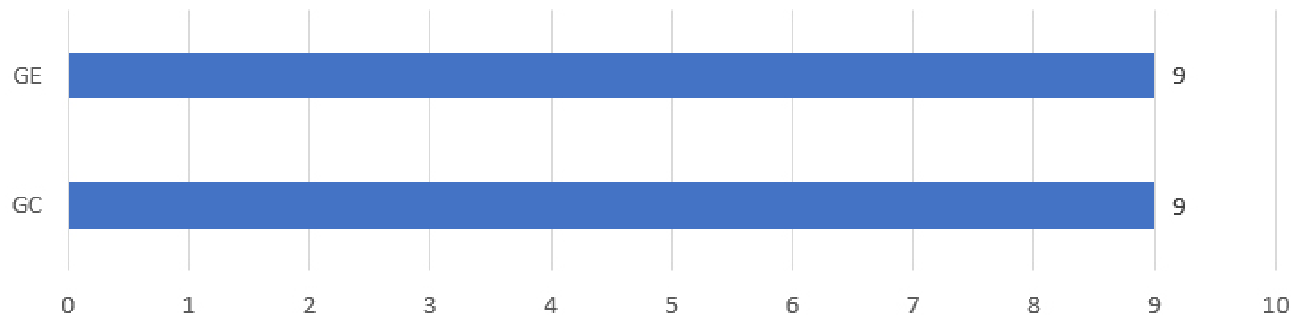
In parallel with the logical analysis and the description of obtained results, we performed non-parametric inferential statistical analyzes for the independent samples and for the paired samples, according to the first axis.

This approach allowed us to gain a deeper understanding of the impact of training program on the subjects and to assess whether there are significant differences in the development of scientific thinking among teachers in the control and experimental groups. Also, to evaluate the effectiveness of the scientific thinking training program, we calculated *the effect's size* for the investigated variables, because, in the context of controversy related to *the null hypothesis* significance testing procedure, the APA (American Psychological Association) requires the calculation and reporting of the effect size as a mandatory requirement [3].

In order to compare the level of scientific thinking among teachers from the control group (CG) and the experimental group (EG), we used a scale made up of 9 items that focused on topics of application and integration of knowledge regarding scientific thinking and its pecularities. This section focuses on determining *the quality of procedural knowledge*. This allowed us to identify why teachers are capable of providing practical information regarding the development and efficiency of scientific thinking.

In the experimental research we used *the U-Mann Whitney* Test in order to verify the homogeneity of the control and experimental groups. The sample did not identify significant statistical differences between the control group (CG) and the experimental group (EG) in *the procedural knowledge* variable (U=9865,000, p=0.437). The graphic representation can be seen in Figure 1.

Fig. 1. Median of Scores for CG/Pretest and EG/Pretest on Procedural Knowledge Variable.



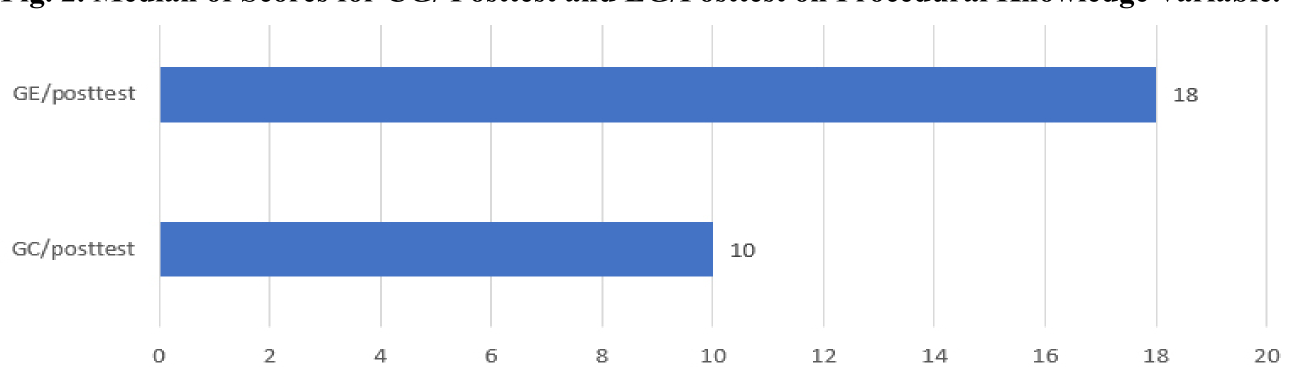
The median of scores at pretest stage were the same for the experimental group (EG) and the control group (CG), both having a median of 9.0 and 9.0, respectively. The next step focused on identifying differences between EG and CG after the experimental intervention at the post-test stage.

Table 1. Analysis of Group Differences by Means of U-Mann Whitney Test

Test Statistics[a]	
	Procedural Knowledge
Mann-Whitney U	4842.500
Wilcoxon W	15282.500
Z	-7.945
Asymp. Sig. (2-tailed)	**0.001**
a. Grouping Variable: EG/CG (Group)	

The U-Mann Whitney test allowed us to identify significant differences between the Control Group (CG) and the Experimental Group (EG) in *the procedural knowledge* variable (U=4842.500, p=0.001). The graphic representation can be seen in Figure 2.

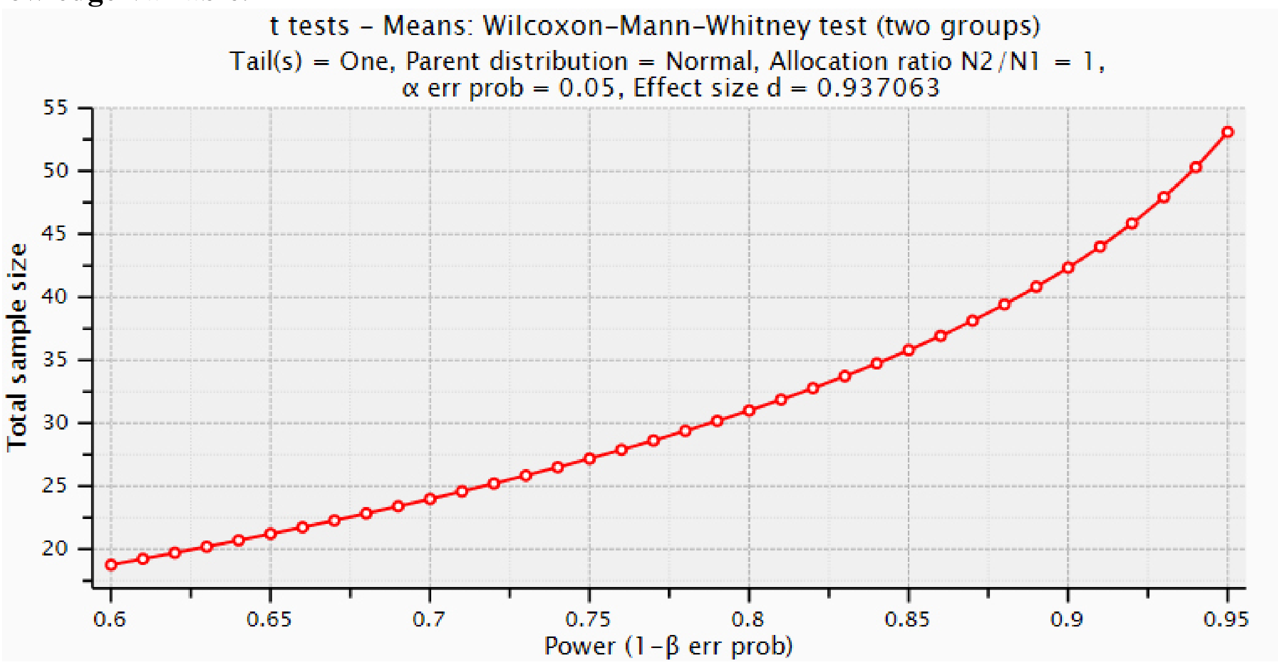
Fig. 2. Median of Scores for CG/ Posttest and EG/Posttest on Procedural Knowledge Variable.



The median of scores on the procedural knowledge variable for EG/posttest were significantly higher (median = 18.0) compared to CG/ posttest (median = 10.0).

The effect size of the experimental intervention on *the third part of the questionnaire* can be visualized in Figure 3 and indicates that the training intervention has the following consequence: *an obvious increase in* **procedural knowledge** (d = 0.93).

Fig. 3. Graphical Representation of Confidence Intervals for Effect Size Indices for Procedural Knowledge Variable.



The obvious increase in *procedural knowledge* is manifested through the development of metacognitive skills and transversal competences/ at the level of optimal integration in the formal and non-formal educational process through the development-application of planning, monitoring, evaluation, regulation, restructuring, interpretation, generalization, argumentation, prediction strategies of complex educational phenomena (in fact, constitutive elements of scientific thinking). More precisely, the teaching staff has become much more confident in solving pedagogical problems and dilemmas, including the various tasks that require the teaching staff in the position of creative and reflexive executor, efficient organizer and well-versed expert. At the same time, the significant increase in procedural knowledge was manifested through the following:

Independence: The possession of procedural knowledge led to an increase in the level of self-actualization and professionalization, to the manifestation of metacomprehension (knowledge of one's comprehension processes) and intellectual autonomy.

Logics and creativity in carrying out tasks: Advanced ability to consistently and coherently develop and apply judgments and reasoning; ensuring the cause-effect relationship in carrying out pedagogical tasks; the manifestation of multiple intelligences, the utilization of convergent and divergent thinking, etc.

Efficiency in execution: Teachers have become better able to develop assignments with fewer errors and in a shorter time due to knowing the correct procedures and appropriate techniques.

Adaptability: Deep understanding of procedures allows them to be adapted to varied or unexpected situations without affecting the quality or effectiveness of tasks.

Quality improvement: The deeper (complex) the knowledge of the procedures was, the more teachers were able to perform tasks with a higher quality, avoiding errors or unexpected difficulties.

Developing strategies: Teachers developed their own strategies to approach tasks and procedures in a more effective and creative way, based on their knowledge.

Knowledge transfer: Teachers were able to more effectively apply procedural knowledge in similar situations or in other fields, transferring declarative/theoretical knowledge and acquired skills.

Development in expertise: During the course of experiment and constant practice, teachers have reached a high level of competence and expertise in a certain field and in solving certain types of problems. Increasing procedural knowledge is not only about learning existing procedures step by step, but also developing the ability to adapt them, understand the context and find innovative solutions in various situations.

The next sequence of the experimental method materialized in making comparisons for paired samples by means of the Wilcoxon test.

In order to investigate to what extent the changes listed above are due to the training program/ development and streamlining of scientific thinking among teachers, the results obtained in the EG in the pretest and posttest, as well as the results in the CG in the pretest and posttest stage, were examined.

Table 2. Analysis of Differences in EG for Procedural Knowledge Variable by Means of Wilcoxon Test[a,b].

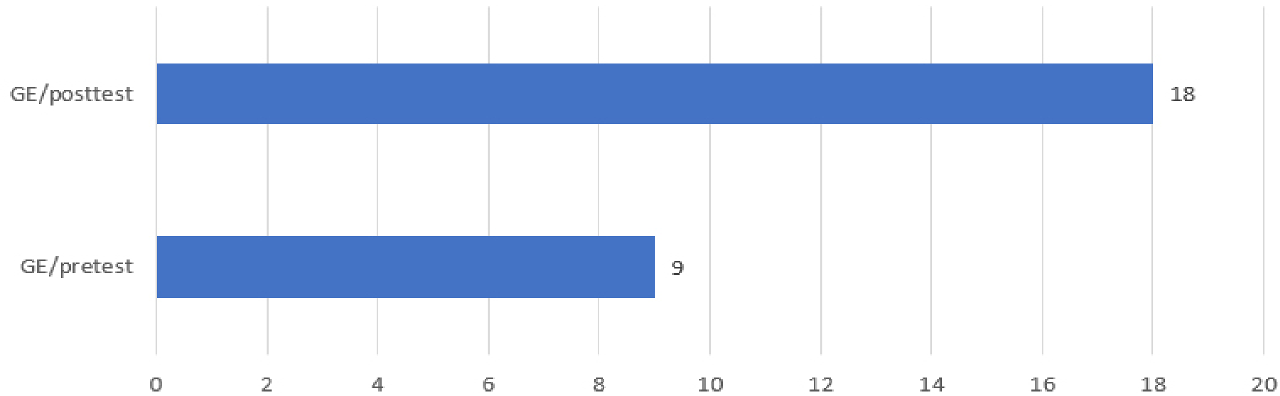
Test Statistics[a,b]	
	Procedural Knowledge
Z	-10.884[c]
Asymp. Sig. (2-tailed)	0.001
a. EG/ CG (Group) = EG b. Wilcoxon Signed Ranks Test c. Based on negative ranks.	

By means of the Wilcoxon statistical test, the differences in EG are compared between the measurements made before the intervention for each separate subscale of the test for evaluation of the scientific thinking in teaching staff, the segment dedicated to procedural knowledge and those made after the experimental intervention.

Statistics and p-values are presented as follows: (Z=-10.884 and the asymptotic (2-tailed) p-value is 0.001.)

Negative Z-statistics suggest that posttest measurements are generally lower than pretest measurements for each individual subscale. Extremely low p-values less than 0.05 (all are 0.001) indicate that the observed differences are statistically significant, meaning that the probability of obtaining the observed differences by chance is very small.

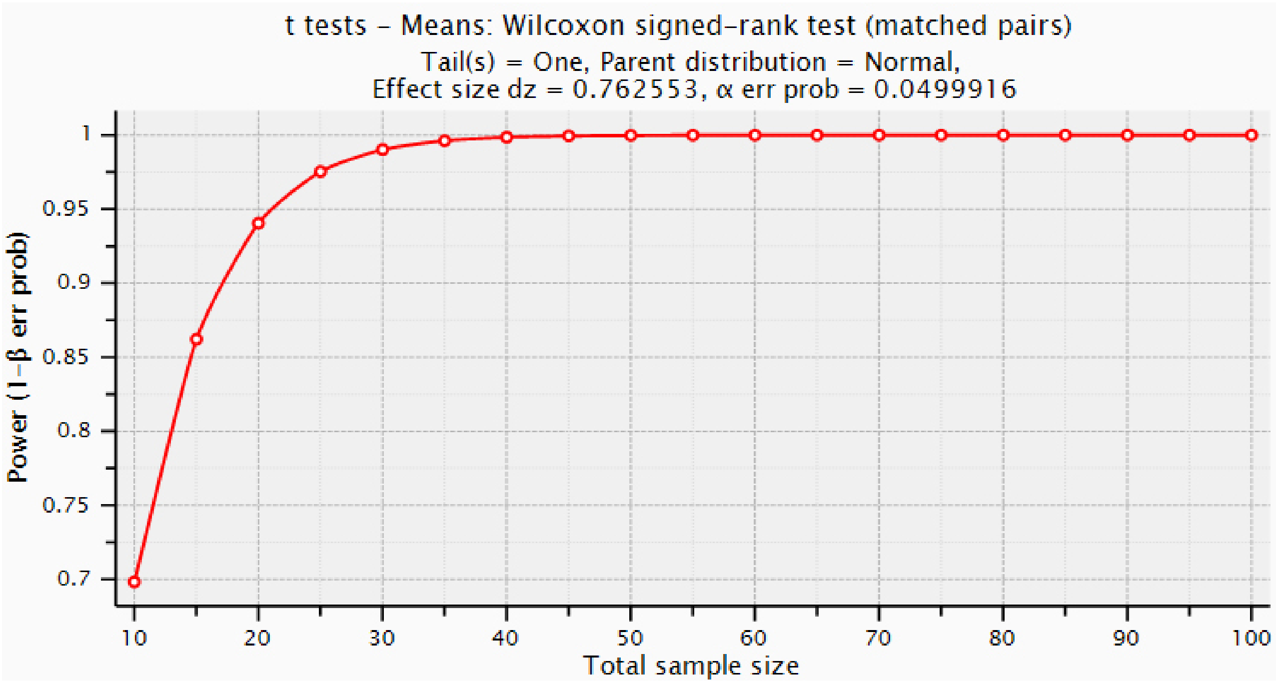
Fig. 4. Median of Scores for EG/ Pretest and EG/Posttest on Procedural Knowledge Variable.



The median of scores for the *procedural knowledge* variable within the experimental group (EG) were analyzed at two different times: pretest and posttest. The results indicate the following significant trends: the median posttest scores (median = 18) were significantly higher than the pretest (median = 9), indicating a significant improvement in ***procedural*** knowledge performance.

These observations suggest that the experimental intervention had a significant positive impact on the development of scientific thinking among teachers in the experimental group (EG). For a more comprehensive perspective, it is recommended to consider other factors and the corresponding statistical analysis, which are not presented in this article.

Fig. 5. Graphical Representation of Confidence Intervals for Effect Size Indices for Declarative, Factual and Conceptual Knowledge Variable.



The effect size of the experimental intervention on *the first part of the questionnaire* can be visualized in Figure 5 and indicates that the training intervention has the following consequence: an obvious increase in procedural knowledge, a significant effect of the experimental intervention (d=0.76) with a level 95% confidence.

Overall, these results indicate that, at the specified sample size, with the established significance level and specified effect size, the probability of detecting the desired effect is close to 95%, thus reflecting adequate test power.

Table 3. Analysis of Differences in CG for Procedural Knowledge Variable by Means of Wilcoxon Test[a,b].

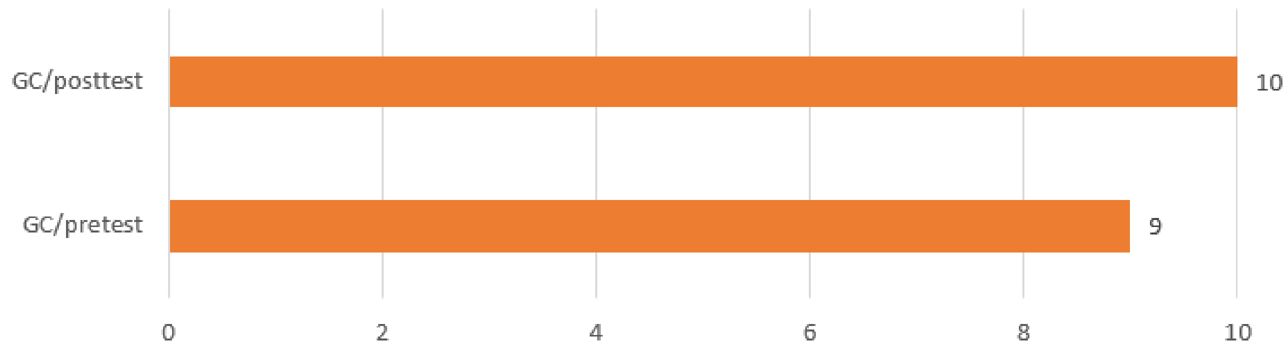
Test Statistics[a,b]	
	Procedural Knowledge
Z	-1.095[c]
Asymp. Sig. (2-tailed)	0.273
a. GE/GC (Group) = CG b. Wilcoxon Signed Ranks Test c. Based on negative ranks.	

For the procedural knowledge variable, we calculated the Z-values, obtaining Z = -1.095, and the asymptotic p-value (2-tailed) is 0.273. The Z value is close to zero, suggesting that there are no significant differences between pretest and posttest measurements for this procedural knowledge subscale within the control group. Also, p-values are greater than 0.05 in all cases, indicating that the observed differences are not statistically significant.

In conclusion, the results reflected in Table 4 suggest that there were no changes in the posttest measurements compared to the pretest measurements in the control group (CG).

We analyzed the median of scores for the procedural knowledge variable within the control group (CG) at two distinct stages: pretest and posttest. The results showed that the median of scores remained constant between the two stages: Median pretest (CG): 9, Median posttest (CG): 10. Therefore, the scores in the control group did not register significant changes between pretest and posttest for the variable procedural knowledge with reference to the development of scientific thinking. This indicates that the control group did not show significant improvements in the development of procedural knowledge related to scientific thinking compared to the experimental group.

Fig. 6. Median of Scores for CG/ Pretest and CG/Posttest on Procedural Knowledge Variable.



Overall, the results suggest that the experimental intervention had a positive impact on the development of scientific thinking in terms of procedural knowledge among teachers in the experimental group (EG). On the other hand, the constant results in the control group (CG) indicate that this group did not register significant improvements in the given knowledge related to the development-efficiency of scientific thinking during this period.

Conclusions

Following the experimental approach, we came to the conclusion that the development of scientific thinking in pedagogues requires the simultaneous activation of procedural knowledge related to scientific thinking. Procedural knowledge, which refers to the practical, complex applicability of theoretical information and their awareness, has a fundamental role in the development of scientific thinking in teachers. This knowledge enables teachers to understand and apply concepts, principles and heuristic strategies in different teaching areas. Procedural knowledge provides a solid foundation for operationalizing scientific thinking in order to obtain relevant results regarding various contexts addressed in everyday life. This knowledge can help teachers convey accurate information to students and strengthen their understanding of scientific topics and beyond. Procedural knowledge is essential to the development of scientific thinking because it enables teachers to make connections between ideas and think critically in the scientific context. The way in which declarative knowledge interacts is achieved through independence in task performance and fluency in execution, better adaptability, the ability to qualitatively transfer knowledge, development in expertise. The development of scientific thinking in teachers is not possible only through knowledge, but through the simultaneous development of procedural knowledge. These three types of knowledge work together to provide teachers with a solid foundation for understanding, applying, and communicating scientific thinking to students. These conclusions emphasize the importance of the diversity of knowledge in the development of scientific thinking among teachers and highlight the need for a comprehensive approach in their training.

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