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The impact of a comprehensive neuroscience program on prospective teachers' neuroeducational literacy: An exploration of practice

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ABSTRACT

The aim of this study is to investigate how comprehensive neurobiology training influences the neuroeducational literacy of prospective Kazakhstani teachers. This study used mixed methods. The study had 216 participants. The findings indicated that the study participants found it difficult to identify the factors influencing the development of their neuroeducational literacy which indicated a lack of understanding by prospective teachers of the meaning of neuroeducation as well as the essence and features of neuroeducation. The neuroeducational literacy of the participants developed linearly and was integrated into the educational practice of the pedagogical university during the experiment. The use of the author's comprehensive instructions on neurobiology significantly increased neuroeducational literacy and also contributed to the professional development and successful educational practices of prospective teachers. These results make a practical contribution to research on the development of neuroeducational literacy among prospective teachers and can be implemented in pedagogical universities representing a new direction in preparing future specialists for neuroeducational activities.

Contribution/Originality: This study contributes to the existing literature by assessing the impact of comprehensive neuroscience instruction on prospective teachers' neuroeducational literacy in Kazakhstan to identify new perspectives and access to scientific knowledge in neuroeducation as well as the practical application of this knowledge to support professional development and successful educational practice.

1. INTRODUCTION

The feasibility of incorporating neuroeducational achievements into primary school teachers' activities is supported by our country's main educational regulatory documents. The law "on education" specifically requires teachers to consider students' psychophysical development. According to the state educational standard for primary general education, the neurodidactic aspect of a teacher's activity is linked to the paragraph "Psychological and pedagogical conditions for the implementation of a primary general education program" and can be viewed through the lens of the teacher's pedagogical competence (Nagima et al., 2022; Zhakupova, Mankesh, Kyakbaeva, Karimova, & Omarova, 2022).

A primary school teacher's neuroeducational activity includes developing neurodidactic technology for transmitting and monitoring knowledge which is implemented in an educational environment that provides students with adaptive intellectual support (Caballero & Llorent, 2022). This will result in more effective student integration into the cognitive educational environment (Ospankulov, Zhumabayeva, & Nurgaliyeva, 2023). The teacher's neuroeducational activity includes monitoring students' individual characteristics and functional state which is primarily accomplished through ergonomic non-contact methods (Baena-Extremera, Ruiz-Montero, & Hortigüela-Alcalá, 2021). On the one hand, it makes it possible to customize educational resources and adds motivational factors. On the other hand, it is more efficient to distribute them within the allotted teaching time. Observe students' psychophysiological reserves and current functional state throughout the flexible arrangement of their educational paths (Thomas, Ansari, & Knowland, 2019). This can have a significant impact on how effectively students learn new information (Fragkaki, Mystakidis, & Dimitropoulos, 2022).

State policy prioritizes children's well-being and growth while in school. However, the challenge of maintaining health in Kazakh schools stems from a tension that exists between the growing number and complexity of subjects to be learned and the curricula and programs. In addition, 80% of students experience school stress, teachers and parents are inadequately competent at managing schoolchildren's mental activities and students' physical activity and nutrition are poorly managed. These difficulties cause chronic overload and deterioration in students' neuropsychological health (Craig, Wilcox, Makarenko, & MacMaster, 2021). Students develop neurotic disorders due to neuro-traumatic factors such as a heavy educational workload and a lack of time for information assimilation.

In this context, changes are needed in the organizational, content and technical aspects of the learning process in primary schools in Kazakhstan. It is necessary to look for constructs that accurately reflect students' ability to maintain and improve their health. One of these concepts is neuroeducation. It closely relates to educational valueology and influences the didactic process's content and health-saving dynamics. The integrative unity of using valeologically appropriate neurodidactic technologies and techniques will increase students' cognitive activity.

At the same time, the question arises: how can neuroscience be used to enhance education? Unfortunately, our country's educational system is not based on new scientific knowledge about neuroeducation and does not fully use it as reality requires. There has not been a great deal of research on neuroeducation for teachers despite the fact that its benefits are becoming increasingly recognised. No Kazakhstani school has frequently used neuroeducational techniques despite the fact that the majority of teachers are eager to use the data. Neuroeducational support for future teachers during their professional development at the university can be extremely useful in resolving these issues. Thus, it is necessary to address the following key question for the development of neuroeducation in Kazakhstan: how to ensure the incorporation of neuroscience achievements (primarily the neurobiology of cognitive activity) into pedagogical practice, thereby increasing the competence of teachers in neuroscience?

1.1. Questions for Research

Q1: How do prospective teachers view the value of neuroeducation?

Q2: How effective is the author's comprehensive neuroscience instruction in fostering prospective teachers' neuroeducational literacy, supporting professional development and successful educational practice?

1.2. Objectives

This research aims to investigate the impact of comprehensive neuroscience instruction on prospective teachers' neuroeducational literacy which provides new perspectives and access to scientific knowledge in neuroeducation as well as the practical application of this knowledge to support professional development and successful educational practice.

The hypothesis is that an author's comprehensive neuroscience instruction will significantly foster prospective teachers' neuroeducational literacy while also supporting their professional development and successful educational practice.

1.3. Significance of the Study

This study is significant because it addresses a pressing problem of neuroeducational literacy among prospective teachers associated with the negative impact of the consequences of using neuroeducation in primary schools in Kazakhstan. However, neuroscience in Kazakhstan is still at an early stage of development due to the lack of comprehensive scientific research and no school has begun to use neuroeducational methods regularly. The presence of neurotechnologies in education is still not significant. The Kazakhstani pedagogical community is not as interested in brain-based learning despite the fact that it also aims to improve the educational process and the level of educational activities. This study adds to the existing literature by investigating the impact of comprehensive neuroscience instruction on prospective teachers' neuroeducational literacy which provides new perspectives and access to scientific knowledge in neuroeducation as well as the practical application of this knowledge to support professional development and successful educational practice. It will also include information on the potential benefits and risks of using neuroeducation and provide the basis for the creation of research-based recommendations for the use of neuroeducation in general education settings. This study is significant because it can provide valuable information about the potential benefits of developing future teachers' neuroeducational literacy. It can be implemented in teacher education institutions representing a new direction in preparing future professionals for neuroeducational work.

2. LITERATURE REVIEW

One of the goals of neuroeducation is to integrate neuroscience knowledge into the educational process in order to develop effective educational technologies (Xu, Cheng, Wang, Wu, & Xiong, 2022). Teachers' understanding of neuroconcepts which reveal the principles of neuronal processes such as memory, emotion and contextual learning allows them to plan educational material presentations in a different order (Schwartz, Hinesley, Chang, & Dubinsky, 2019). However, Chang, Schwartz, Hinesley, and Dubinsky (2021) indicate that researchers are unable to definitively determine what the true "contribution" of neuroscience to education is whether or not neuroscience can be expected to identify effective teaching methods, how and under what circumstances the theory can be tested in children's classrooms and what the limitations of neuroimaging methods in teaching in classroom contexts are.

There is also no definitive answer to the question of whether current anatomical knowledge of the brain is adequate to explain the mental processes involved in learning (Sweller, 2020). The history of neuroeducation's development and convergence with teaching practice demonstrates that being familiar with the most recent neuroscience data and neuroresearch findings can help teachers select and correctly implement the most effective educational strategies (Jolles & Jolles, 2021). However, the challenge of distinguishing between genuine data in neuroeducation and "neuromyths" persists (Blanchette, Sarrasin, Riopel, & Masson, 2019). Neuromyths are false beliefs about brain development and function that have arisen due to misunderstandings, misinterpretations or miscitations of evidence-based facts (from brain research) to justify the use of brain research in education (Ruiz-Martin, Portero-Tresserra, Martínez-Molina, & Ferrero, 2020). Furthermore, the majority of teachers are willing to base their lessons on unconfirmed or misinterpreted neuroeducation research findings (Benneker et al., 2023; Hughes, Sullivan, & Gilmore, 2021; Wilcox, Morett, Hawes, & Dommett, 2021). According to the researchers, age, professional experience and the subject matter of teaching have no influence on the proliferation of neuromyths. The primary group of neuromyths is prevalent despite the educational system and culture (Bissessar & Youssef, 2021; Grospietsch & Mayer, 2019; Valdez et al., 2019). Almost all researchers attribute the widespread dissemination of neuromyths to teachers' lack of critical evaluation of neurobiological findings and "translating" experimental data into educational practice (Carter, Van Bergen, Stephenson, Newall, & Sweller, 2020; Rogers &

Cheung, 2020; Thomm, Gold, Betsch, & Bauer, 2021). This results in oversimplification and misinterpretation of brain research findings as well as attempts to draw a direct line between these studies and the teacher's practical actions. The problem is that while neuromyths contain some element of truth, their interpretation is simplified or distorted. According to surveys, more than half of teachers are unable to identify neuromyths and believe that this is scientifically sound information that should be used in practice (Deibl & Zumbach, 2023; Simoes et al., 2022; Vig et al., 2023). Furthermore, it was found that reading popular science journals and having a general understanding of this subject matter do not help identify neuromyths and reinforce belief in them (Im, Cho, Dubinsky, & Varma, 2018). The aforementioned indicates that teacher preparation and retraining in addition to the participation of working teachers in educational neuroscience research have great significance in developed countries. Unfortunately, Kazakhstan lacks comprehensive scientific research on neuroeducation which impedes the integration of neuroscience advances into pedagogical practice. Neuroresearch in education is uncommon and most recent discoveries in the field of neuroscience are unknown to Kazakh teachers despite Kazakhstan's scientific potential and relative achievements in correctional pedagogy.

3. METHOD

3.1. Research Design

This section describes in detail the research strategy, including the main stages, data collection methods, survey response selection methods and the resources required. The design will explain how the data was collected and how the research will be conducted. An experimental design was most appropriate for assessing the changes that occurred as a result of the experimental program. This type of design required the formation of two study groups: experimental and control. It was important that the groups were similar in their key characteristics (e.g., gender, age, place of residence, training, etc.), except for the characteristics being studied (e.g., participation in a training program).

Conclusions about the changes that occurred as a result of the implementation of the program are drawn based on a comparison of the survey results of the EG and CG.

This study used mixed methods. In the quantitative approach, data formalization techniques were employed. Quantitative survey data was collected from participants regarding their scientific knowledge of neuroeducation as well as the practical application of this knowledge and an assessment of their motivation to learn. A qualitative strategy is built around interpretive procedures for data collection, processing, and analysis. Qualitative data through a semi-structured interview was collected from groups and provided the researchers with an opportunity to delve deeper into the participants' perspectives, experiences and perceptions.

3.2. Research Sample Formation

The study included prospective teachers specializing in education from two Kazakhstani universities (Abai Kazakh National Pedagogical University and Kazakhstan National Women's Teacher Training University). The study included 216 prospective primary school teachers between the ages of 18 and 27. The mean age was 24.66 ± 1.1 years (SD 4.2). Students from Abai Kazakh National Pedagogical University made up the EG. The CG consisted of students from Kazakhstan's National Women's Teacher Training University. All respondents were female as there were no male potential primary school teachers among the study participants. The author's comprehensive neuroscience instruction for learning was used for EG participants while traditional training methods were used in the CG.

The independent variables were the results of the techniques used to diagnose participants' neuroeducational literacy before and after the author's comprehensive neuroscience instruction. The impact of outside variables on the dependent variable was minimized by following the rules for subject selection and experimental conditions.

3.3. Measures

General sociometric indicators were collected including gender, age, course of study, level of preparation for the pedagogical education program and direction of study (see Table 1).

Table 1. Descriptive information provided by respondents.

Descriptive information about a respondent's		Quantity	Sample
Gender	Female	216	100%
	Male	0	0
The areas of study	Pedagogical	216	100%
Student training course	2 course	216	100%
EG	Abai Kazakh National Pedagogical University	105	50%
	Male	0	0
	Female	105	50%
CG	Kazakh National Women's Teacher Training University	111	50%
	Male	0	0
	Female	111	50%

3.4. Data Collection Tools

This section of the research delves deeply into the data collection tools. The researchers used a questionnaire and an interview to evaluate the impact of the information-gathering tool on the comprehensive neuroscience program and neuroeducational literacy.

3.4.1. A Technique for Assessing Students' Educational Motivation

An important aspect of developing students' interest in scientific knowledge in the field of neuroeducation is motivation. In this context, groups of motivational factors have been identified that characterize students' attitudes towards neuroeducation and assess the degree of relationship between their use and students' interest based on an ordinal rating scale called a Likert scale. The use of this method makes it possible to obtain quantitative estimates of respondents' attitudes, suitable for analyzing the expression of interest in the aspect under study measured on a rank scale. In practice, an ordinal rating scale is used for respondents to express their agreement or disagreement with proposed judgments characterizing the object of study on which the analysis is based. The survey questionnaire included ten questions on five different scales (see Table 2). The positive attitude of the student towards the question is marked with a larger number (5), and a negative one is coded with a smaller one (1) because there are no negative statements in our study. It should be noted that the scores obtained are summed across all judgments.

Table 2. À questionnaire content.

N	Questions
1	A better knowledge of neuroeducation could help with classroom instruction and learning.
2	One of the objectives of neuroeducation is to integrate neuroscience knowledge into the educational process.
3	Teachers using neuroeducation change their methodological approaches to teaching.
4	Understanding neuroconcepts which reveal the principles of neuronal processes of memory, emotions and contextual learning improves teaching and learning.
5	Knowledge concerning neuroscience benefits the professional development and educational practice of students.
6	Although brain-based learning has significant importance, its application in teaching and learning can be difficult without special training.
7	Comprehensive neuroscience instruction improves prospective teachers' neuroeducational literacy, supports professional development and fosters successful educational practice.
8	Better knowledge concerning underlying learning and memory might improve teaching.
9	There is a strong relationship between mental abilities, emotional and cognitive intelligence and academic achievement.
10	The neuroscience instruction will significantly foster prospective teachers' neuroeducational literacy and provide new perspectives and access to scientific knowledge in neuroeducation.

3.4.2. The Interview on the Value of Neuroeducation

The interviews were conducted to learn more about the respondents' experiences, educational level, interest in neuroscience and sources of neuroscience information. The interview also sought to determine why respondents answered survey questions in a specific manner which varied depending on how they completed the survey. When conducting a semi-structured interview, the conversation was free and questions of interest to the interviewer were organically integrated into the story as clarifications without disrupting the overall flow of the conversation, or questions were asked at the end of the conversation. Thus, the semi-structured interview provided the researchers with an opportunity to delve deeper into the participants' perspectives, experiences and perceptions. The interview was divided into two parts. In the first section, we attempted to elicit specific areas of interest through open-ended questions or comments instead of closed-ended questions. Individual questions were formulated during the interview based on the context. The interview lasted an average of 40 minutes but it was longer depending on the respondent's level of understanding and literacy (for example, respondents with language problems who lacked perfect knowledge of the Kazakh language) or those who were very talkative or had many difficulties due to their health condition which took time to answer all questions. Audio recording was the method used to record interviews. Responses from interview participants were saved for further analysis and clarification.

3.4.3. Role of the Expert

The assessor's role is to ensure that the interviewers do a good job. This includes survey logistics, collaboration with other team members and observation. Observing interviewers was done before, during and after each interview. The assessors examined not only whether the contact procedure was followed but also whether the interviews were carried out correctly. They conducted 6-10 interviews per interviewer with 4-6 at the outset and the remainder at various stages of data collection. The expert ensured that standardized interview methods were followed during the undirected voicing of questions, clarifications, "probing" and feedback. They also double-checked the data after the interviews to ensure it was properly coded and entered. Experts provided feedback and reports on a regular basis to keep the organization in charge of the study updated on the survey's progress and any issues that arose.

3.4.4. Reliability Study

Interviewing respondents with the same instruments and using the same selection process demonstrated the sample's reliability.

3.4.5. Validity Study

Validity refers to the ability to measure precisely the characteristics that are intended to be studied during the study.

3.5. Research Approach

The experiment consisted of the following stages:

(1) The ascertainer determined the study participants' initial level of neuroeducational literacy.

(2) The formative approach aims to implement an author's comprehensive neuroscience instruction for the experimental group. This instruction covers a wide range of topics such as the neuronal mechanisms of learning, the morphological and functional genesis of the brain, the neurophysiological potential of general abilities, mental actions in educational practice, universal educational actions and the specific neuropsychological and neurophysiological characteristics of students. Daily reflections revealed how the neuroeducation content affected each participant.

According to the developed methodology, training lasted 4 credits over one semester (30 weeks/60 hours) with two academic hours of 50 minutes per week (see Table 3).

Table 3. Study load breakdown.

Study load	Number of academic hours (Fall term)
Classroom work	30
Consultation	6
Seminar	2
Training	4
Lecture	16
Practical lesson	2
Independent work of students	30
Milestone testing	4
Project assignment	4
Note-taking	10
Solving a complex pedagogical problem	6
Preparing a flowchart	4
Final control (Test)	2

The author's comprehensive neuroscience instruction pedagogical design assumed that both spiral and linear forms of training could be used. A linear form was used to test the technique due to the short duration of the experiment. The acquired basic knowledge, skills and abilities can be expanded through independent work and attendance at specialized courses and seminars devoted to specific aspects of neuroeducational literacy development with sufficient personal motivation from students. During the introductory lesson, students were given a thematic plan that allowed them to independently consider the questions for study, additional material and literature at their discretion and at a convenient time.

(3) Control: (a) determine the dynamics of all components and the integral indicator of neuroeducational literacy in the CG. (b) Identify similar dynamics and patterns in the EG. (c) Compare the results of repeated diagnostics in the EG and CG.

The structure of future specialists' readiness for neuroeducational activities reveals the content-static characteristics which represent the interconnection and interdependence of the motivational, cognitive and operational components.

At each stage, components are developed in three stages which correspond to three levels: basic (initial), formative (average) and adaptation-integrating (advanced).

3.6. Ethical Compliance

Ethical issues were among the most important considerations in organizing educational research. The first requirement for engaging students in empirical research was their voluntary consent. It was the researcher's direct responsibility to provide potential participants with comprehensive information about the risks of participating in the study in accordance with the principle of voluntary consent. Respondents were informed about the study's confidentiality and anonymity that there are no rights or wrong answers that any point of view is valuable and that they could choose not to answer certain questions before the survey began. Anonymity and confidentiality are closely related concepts. Their implementation assumes that the toolkit contains no data that could be used to identify the respondent and that the information provided is not disclosed to third parties. Respondents were given alphanumeric identifiers that they could use instead of their names in all surveys and assessments.

3.7. Data Analysis

Exploratory factor analysis was employed as a statistical tool for data analysis. Factor analysis was employed in order to minimize the data's dimensionality and find a few contributing factors that accounted for the majority of the variance that was found across a much wider range of manifest variables.

4. RESULTS

Figure 1 shows the results of the technique for assessing students' educational motivation.

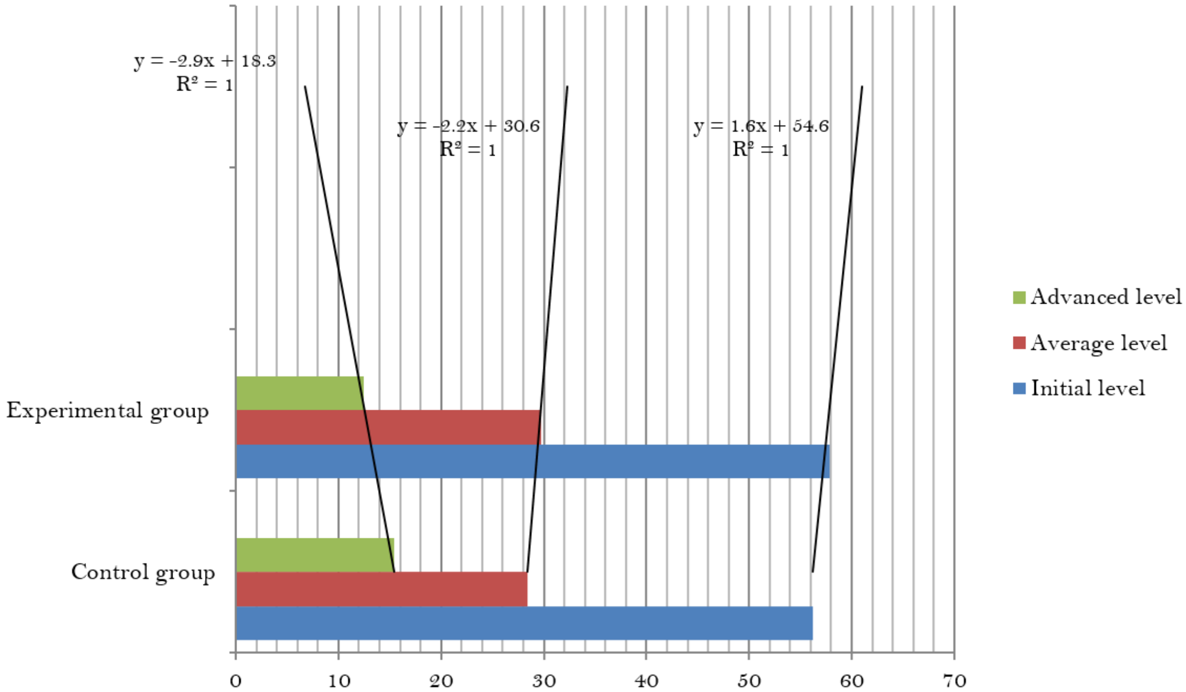

Figure 1. The results of the technique for assessing students' educational motivation.

During the assessment, a group of participants was identified based on their initial motivational component level: 56.2% in the CG and 57.8% in the EG with an average level of 28.4% in the CG and 29.7% in the EG. Only 15.40% of CG participants and 12.5% of EG participants perform at advanced levels.

The evaluation of the cognitive component is shown in Figure 2.

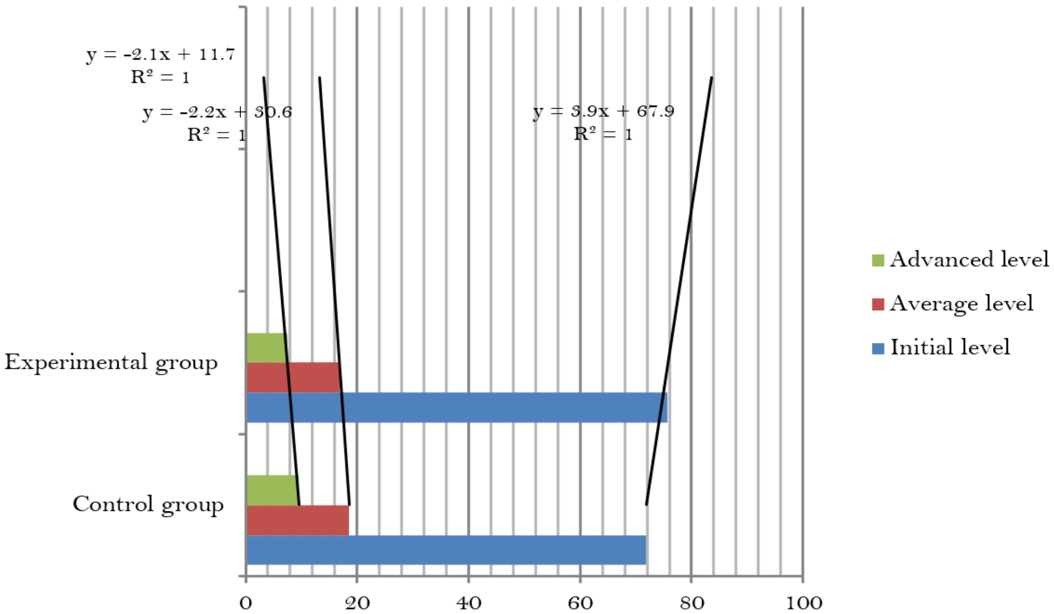

Figure 2. The evaluation of the cognitive component.

According to the cognitive component, the initial and average levels were observed in the CG (71.8% and 18.6% of participants) and the EG (75.7% and 16.8%) while participants' advanced level of development of the cognitive component was insignificant in the CG (9.6%) and 7.5% in the EG.

Figure 3 shows the results of assessing the operational component.

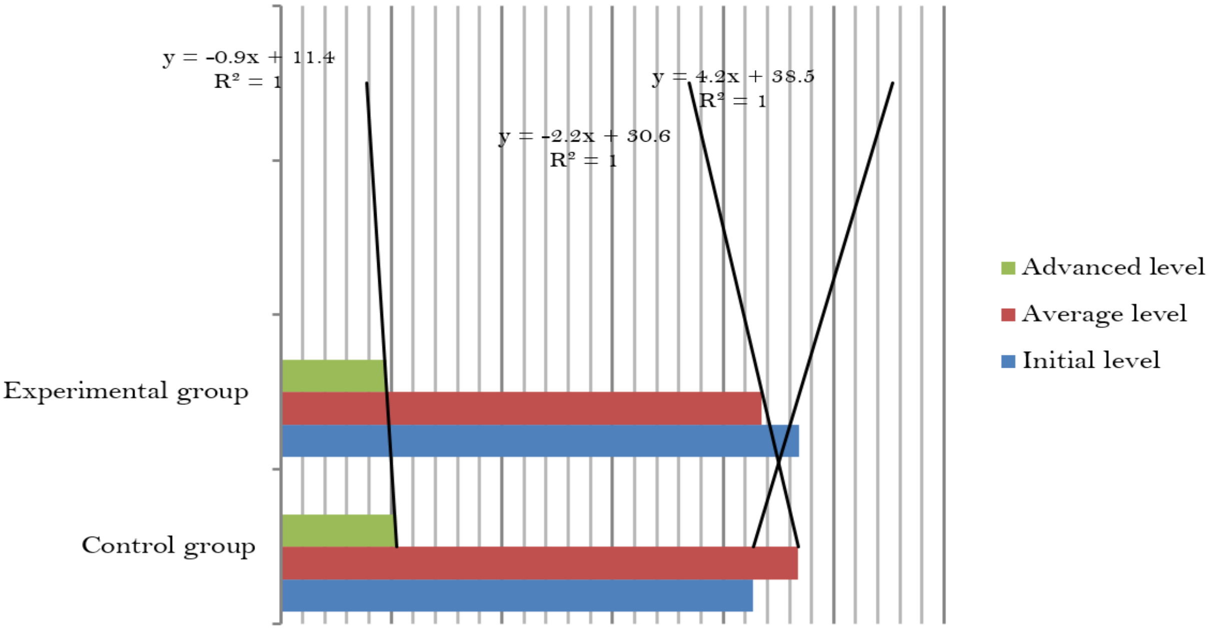

Figure 3. The assessment of the operational component.

According to the operational component, the initial and average levels were observed in the CG (42.7% and 46.8% of participants) and the EG (46.9% and 43.5%) while participants' advanced level of development of the operational component was insignificant in the CG (10.5%) and 9.6% in the EG.

The post-test was conducted to determine the comprehensive effectiveness of neuroscience instruction in fostering prospective teachers' neuroeducational literacy. The control study's students' educational motivation is shown in Figure 4.

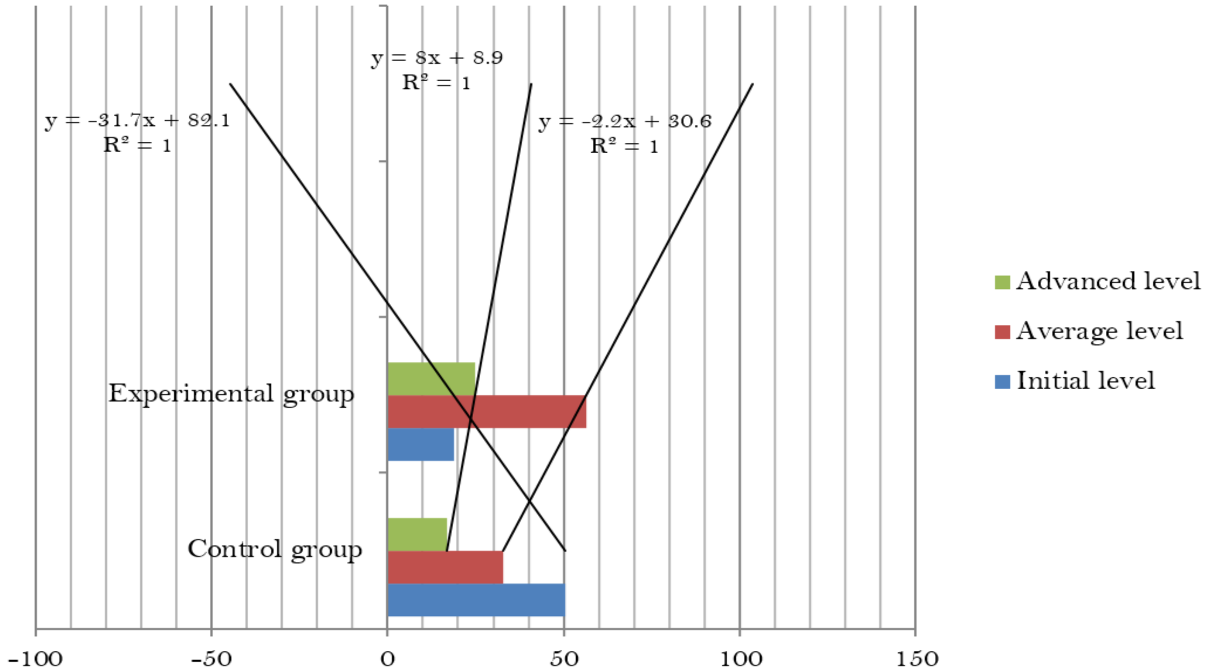

Figure 4. The control study's students' educational motivation.

The EG initial level is 18.7% the average level is 56.4% and the advanced level is 24.9%. The dynamics of the CG outcomes are insignificant. The advanced level went down to 1.5%.

The visual representation of the levels of development of the motivational component of neuroeducational literacy is shown below (see Figure 5).

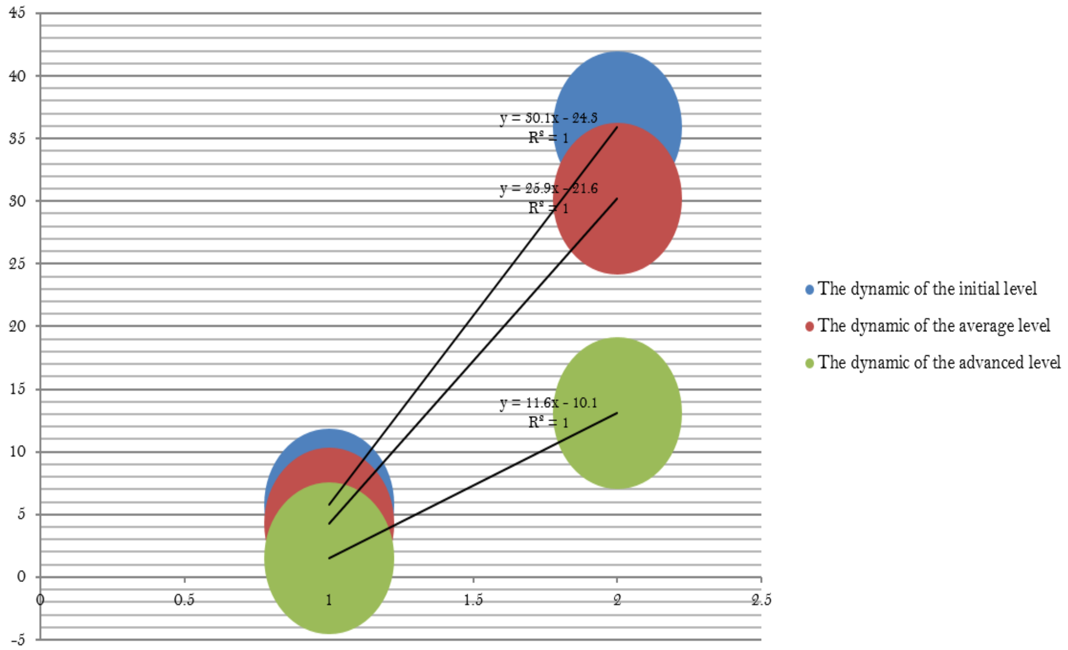

Figure 5. The visual dynamics of the levels of development of the motivational component.

The control experiment results clearly show that in the EG, the initial level has more pronounced negative dynamics (35.9%) due to an increase in the proportion of students at average (30.2%) and advanced levels (13.1%). In the CG, the dynamics of the initial level are much less expressed (5.8%) while the dynamics of the average (4.3%) and advanced (1.5%) levels are practically unchanged.

The evaluation of the cognitive component in the control stage is shown in Figure 6.

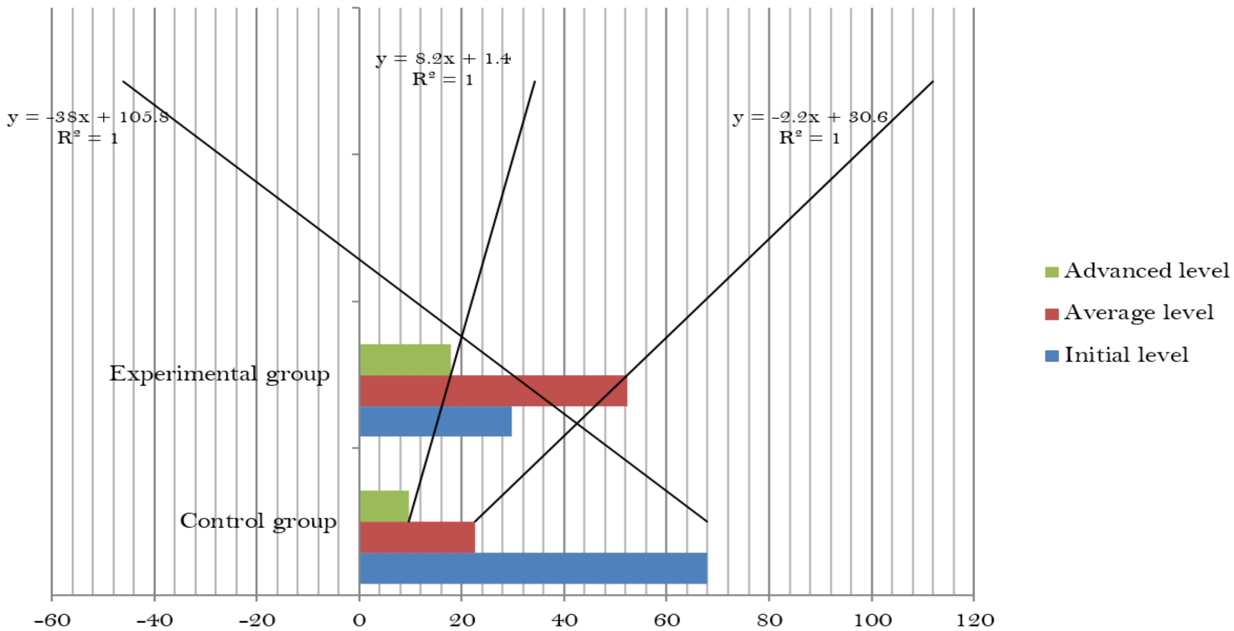

Figure 6. The evaluation of the cognitive component in the control stage.

It is noteworthy that the proportion of participants in the EG with an initial level (29.8%) of the development of the cognitive component decreased sharply while the proportion of students with an average level (52.4%)

increased. At the same time, the proportion of participants with an advanced level of proficiency in this component has increased significantly (17.8%).

The nature of the dynamics of the cognitive component in the CG and EG at the control stage is shown in Figure 7.

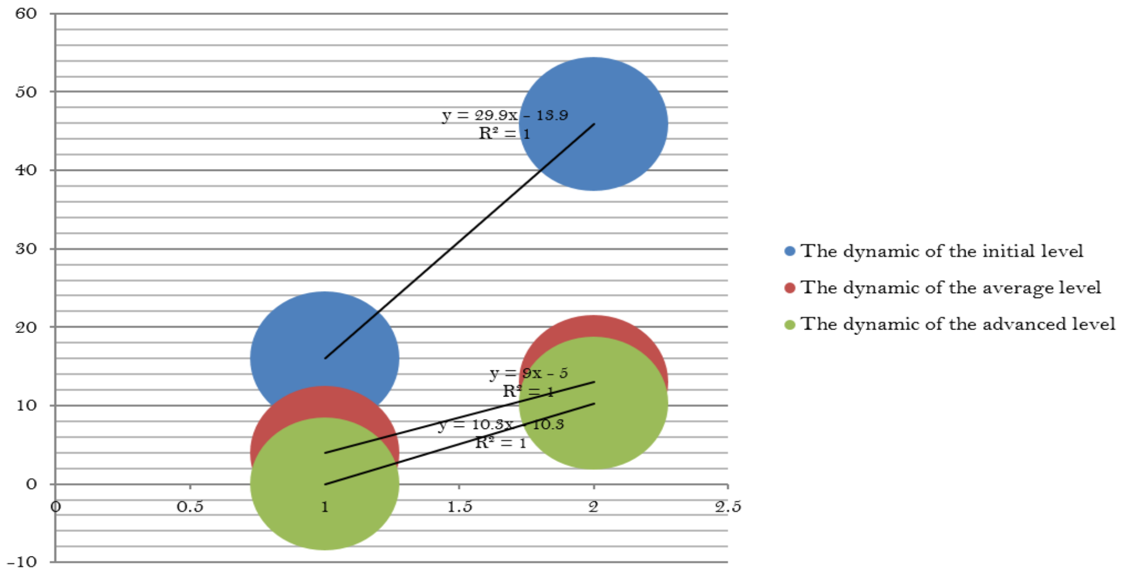

Figure 7. The nature of the dynamics of the cognitive component in the CG and EG at the control stage.

The results show that in the EG, the initial level has more pronounced negative dynamics (45.9%) due to an increase in the proportion of students at average (35.6%) and advanced levels (10.3%). In the CG, the dynamics of the initial level are less expressed (16%) while the dynamics of the average (4%) and advanced (9.6%) levels are practically unchanged.

At the same time, the share of students at the initial level is lower (see Figure 8).

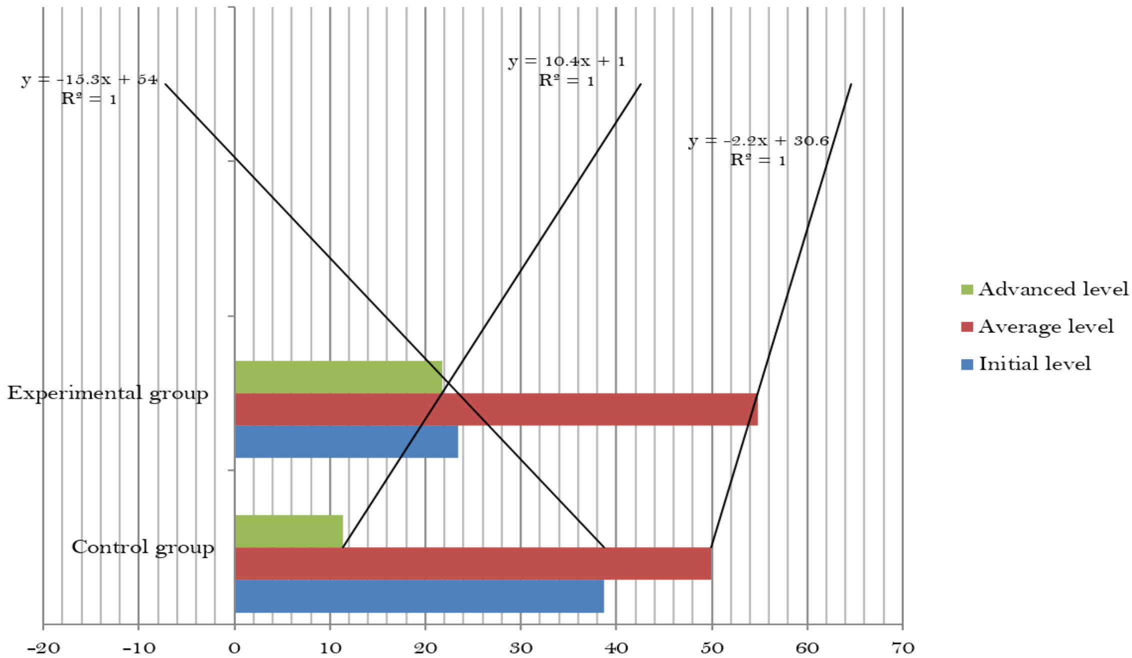

Figure 8. The nature of the dynamics of the operational component in the CG and EG.

The most pronounced growth in the EG is in the proportion of students with an average level (54.8%). However, the growth in the proportion of students with an advanced level is also unexpectedly high (21.8%).

Accordingly, in the EG, there are positive and intense dynamics in the development of the operational component compared to the control group (see Figure 9).

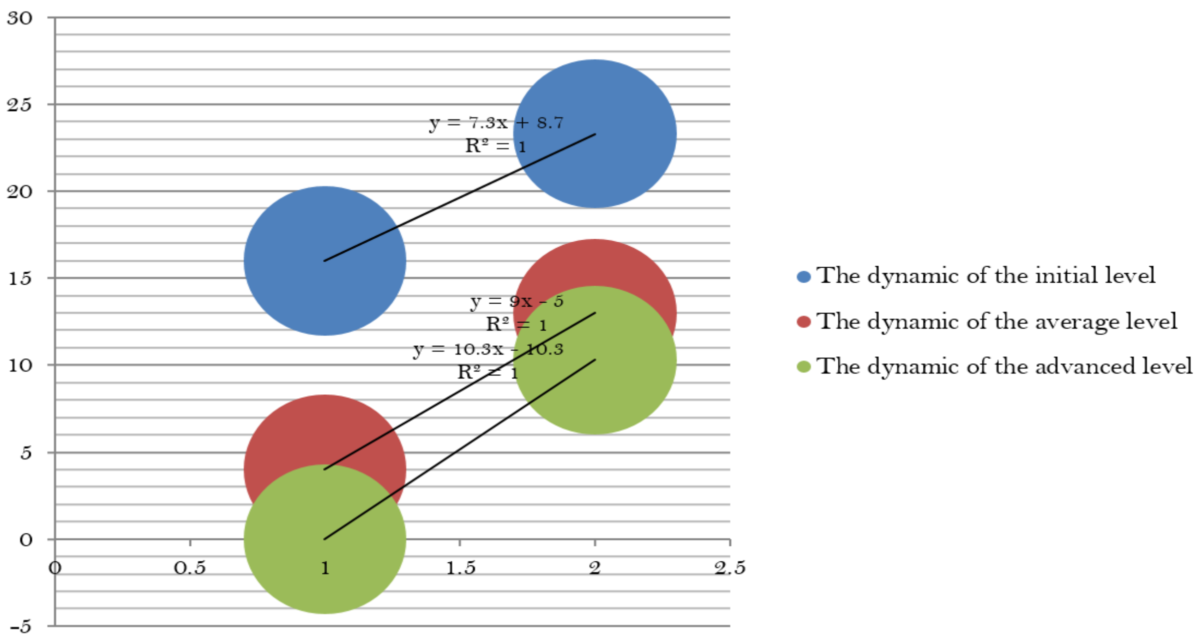

Figure 9. The nature of the dynamics of the operational component.

The results of the EG are much higher than the results of the CG. The advanced level in the EG (21.8%) is greater than that of the CG (11.4%) by 10.4%. The average level in the EG (54.8%) is higher than that in the CG (49.9%) by 4.9%. The initial level in the EG (23.4%) is lower than the CG (37.7%) by 14.3%.

Figure 10 shows a comparison of the EG ascertainment stage and control stage results.

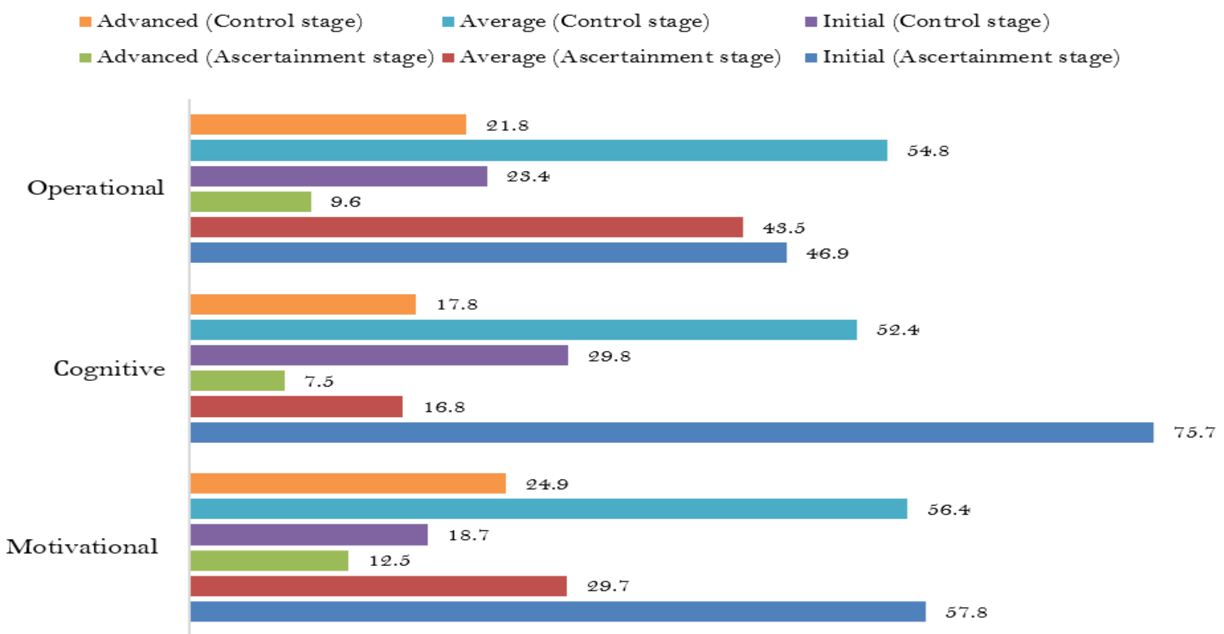

Figure 10. EG ascertainment stage and control stage results.

The control phase findings in the EG have improved both qualitatively and quantitatively when compared to the ascertainment stage results.

The advanced level of the motivational component increased from 12.5% to 24.9%. Thus, an increase of 12.4% was noted. The average level of students increased from 29.7% to 56.4% (an increase of 26.7%). The initial level of students decreased from 57.8% to 18.7% making a difference of 39.1%.

The advanced level of the cognitive component increased from 7.5% to 17.8%. Thus, an increase of 10.3% was noted. The average level of students increased from 16.8% to 52.4% (an increase of 35.6%). The initial level of students decreased from 75.7% to 52.4% making a difference of 23.3%.

The advanced level of the operational component increased from 9.6% to 21.8%. Thus, an increase of 12.2% was noted. The average level of students increased from 43.5% to 54.8% (an increase of 11.3%). The initial level of students decreased from 46.9% to 23.4% making a difference of 23.5%.

5. DISCUSSION

The aim of this study is to investigate how comprehensive neurobiology training influences the neuroeducational literacy of prospective Kazakhstani teachers. In the initial stage, the assessment of the initial motivational component level in the CG and EG was nearly identical. The deviation for each identified level is less than 2% indicating that the experiment began under the same conditions. The inability of the participants in CG and EG to identify the elements impacting the development of their neuroeducational literacy suggests that prospective teachers are unaware of the significance of neuroeducation as well as its basic concepts and specifics. The initial and average levels of the cognitive component were observed in the CG and EG whereas participants' advanced level of cognitive component development was insignificant in the CG and EG. The initial and average levels of the operational component were observed in the CG and the EG whereas the advanced level of development of the operational component was insignificant in the CG and the EG.

According to the findings, prospective teachers' neuroeducational literacy should be fostered. The training followed the author's comprehensive neuroscience instructions: (1) the development of neuroeducational literacy in participants EG occurred linearly and was integrated into the teaching process of a pedagogical university. (2) The component-by-component development of neuroeducational literacy proceeded in parallel and ensured the integration of the professional and personal qualities of participants based on the results of mastering the essence and specifics of neuroeducation resulting in optimal neuroscience instruction training (Dubinsky et al., 2019; Gkintoni, Halkiopoulos, & Antonopoulou, 2022; Sortwell et al., 2023).

The author's comprehensive neuroscience instruction involves the use of techniques and tools to ensure the development of neuroeducational literacy among participants (see Table 4).

Table 4. Methodical conditions for preparing prospective teachers' for the development of neuroeducational literacy.

Structure of neuroeducational literacy	Forms of training	Technologies	Forms
1	2	3	4
Motivational	Passive Active	Situational modeling Lecture project	Multimedia presentations and flip charts
Cognitive	Interactive Passive	Situational modeling Lecture	Multimedia presentations and handouts
Operational	Interactive Passive	Training situational modeling lecture	Multimedia presentations and handouts

The author's comprehensive neuroscience instruction combined four areas to optimize professional training for students in future neuroeducational activities (Weber & Mofield, 2023). The first direction focuses on the formation of a positive attitude towards future professional activities and a positive attitude towards mastering neuroeducation. The second direction is aimed at developing innovative thinking in students, the ability to put forward hypotheses, forecasting, design and modeling in the neuroeducational field and the third direction optimizes the process of forming the will to overcome external and internal barriers when implementing neuroeducational professional activity. The fourth direction ensures the development of empathy, skills of feedback, speaking, listening and reflection in interpersonal and group work.

In the next stage, a method that is comparable to the ascertaining experiment was carried out to (a) detect the dynamics of all components and the integral indicator of neuroeducational literacy in the CG. (b) Identify similar dynamics and patterns in the EG. (c) Compare the results of repeated diagnostics in the EG and CG.

The results of the control stage determine the comprehensive effectiveness of neuroscience instruction in fostering prospective teachers' neuroeducational literacy. This suggests that the targeted development of neuroeducational literacy at each stage separately has a strong stimulating influence on EG after a very short time. Thus, the participants in the EG showed an increase in motivation to study neuroscience and also admitted the value of neuroeducation in the control stage. It was discovered that students are enthusiastic about using neuroeducational strategies and can create goals and approaches to using neuroeducation to predict ways to introduce innovations and develop conceptual foundations and stages of neuroeducation activity (Bei et al., 2023; Ching, So, Lo, & Wong, 2021; Goldberg, 2022).

The survey results revealed that neuroscience instruction increased participants' neuroeducational literacy development. The calculation of correlation and identification of the relationship between a specific issue and a general indicator for the entire group of respondents confirmed the importance of neuroscience instruction for the formation of prospective teachers' neuroeducational literacy. In a nutshell, it can be noted that the importance of motivation is also confirmed by the need to maintain student loyalty to neuroeducation even after graduation for their successful educational practice. For example, when respondents were asked whether neuroscience instruction could be a factor in fostering prospective teachers' neuroeducational literacy and providing new perspectives and access to scientific knowledge in neuroeducation (question 10), the ratings indicated that 94.6% strongly agreed. The survey results proved that using comprehensive neuroscience instruction significantly increased prospective teachers' neuroeducational literacy. The findings also show that component-by-component development of neuroeducational literacy facilitated the integration of participants' professional and personal qualities resulting in optimal professional training for students in future neuroeducational activities (Avvisati, Le Donné, & Paccagnella, 2019; Schmied & Jamaludin, 2023).

Interview results revealed that respondents' neuroeducational literacy is developed throughout their training providing a more in-depth understanding of how prospective teachers perceive the value of neuroeducation (Coch, 2018; Tan & Amiel, 2022).

Thus, the author's comprehensive neuroscience instruction provided participants in the experimental group with useful knowledge that they can apply in their practice.

6. CONCLUSION

This study explored the impact of comprehensive neurobiology training on the neuroeducational literacy of prospective teachers. Neuroeducational literacy in participants' EG developed linearly and was integrated into a pedagogical university's teaching procedure during the experimental process. The component-by-component development of neuroeducational literacy occurred concurrently ensuring the integration of participants' mastery of the essence and specifics of neuroeducation. The use of comprehensive neuroscience instruction in the educational process increased students' positive attitudes towards professional neuroeducational activities, the personal significance of acquired neuroeducational knowledge and the desire to succeed in neuroeducational activities, resulting in optimal neuroscience instruction training. Furthermore, ideas and knowledge about the creative nature of neuroeducational activities of teachers, students' awareness of the need for neuroeducational reorganizations in the professional field, knowledge of the structure and features of the process of solving neuroeducational problems, knowledge of the methodology, theory and technology of neuroeducation and the use of new diagnostic methods and neuroeducational tools. Fostering prospective teachers' neuroscience literacy through comprehensive neuroscience instruction has acquired positive dynamics: (1) prospective teachers see the value of neuroeducation. (2) Students recognize the need to introduce neuroeducation in primary school. (3) They understand the professional and personal importance of the acquired neuroeducational skills, knowledge and competencies. (4) A new perspective on neuroeducation has increased their motivation. The study's findings demonstrated that using an author's comprehensive neuroscience instruction significantly fosters prospective teachers' neuroeducational literacy while also supporting their professional development and successful educational practice.

7. LIMITATIONS AND ADDITIONAL FUTURE DIRECTIONS

The study's findings do not aim to provide a comprehensive description of the solution to the identified problem. Prospects include a broader investigation into the development of a comprehensive understanding of the structure of brain processes that occur within the framework of complex mental activity (counting, reading, writing, etc.) during learning, developing the ability to use the findings of neuropsychological and neurophysiological research to best organize the educational process, reveal students' cognitive potential and successfully design and modernize modern educational technologies.

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Institutional Review Board Statement: The Ethical Committee of the Academic Council, Abai Kazakh National Pedagogical University, Kazakhstan has granted approval for this study on 12 October 2023 (Ref. No.3).
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
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