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Training Pre-Service Math Teachers For Developing Students' Mathematical Culture At School

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Abstract This paper represents the study on training pre-service math teachers and preparing them for developing students' mathematical culture at school. For this purpose, the paper discusses the notion of mathematical culture and the urgency of its development in view of the decreased level of students' math knowledge and skills, revealed by the international testing. The study stresses the necessity to organize such pre - service math teachers' training that would target the development of their psychological and professional readiness to teach at school, equipping them with fundamental math knowledge and skills, proper educational techniques and digital technologies to be applied according to the needs of the learning processes. The paper presents a theoretical model of training pre - service math teachers, designed by the authors on the basis of the literature analysis and successful case studies in this area. The model was tested in the pedagogical experiment with the pre - service math teachers in Kazakhstan. The data obtained from the pedagogical experiment proved the efficacy of the model and teaching methodology suggested by the authors. In conclusion, the main pedagogical conditions for effective pre-service math teachers' training are laid out to be used for designing textbooks, digital teaching tools and materials accordingly.

Keywords pre - service math teachers, mathematical culture, teacher's readiness to teach, pre-service teachers' training, culture, activity, competence, digital technology, ICT.

Introduction

Intensive development of technologies and science, active processes of science integration into production and industry, global processes of business internationalization require high levels of professionalism from in-service employees and those who are just about to enter a job market.

Among the competences and skills required, math literacy occupies one of the most important places serving as an indicator of a personality's intellectual development, their abilities to think logically, consistently, operate with abstract notions, conduct necessary calculations and solve professional problems adequately.

With these concerns, young people, who are leaving schools, looking for continuation of their education and making professional choices, are expected to possess substantial knowledge and skills in math alongside general literacy, language competences and other qualities which are crucial for life and work in modern conditions.

Though recent analysis of the current state of the quality of math education at school in Kazakhstan shows an insufficient level of the students' mathematical literacy. The implementation of the international PISA tests in schools of Kazakhstan revealed insufficient level of the school graduates' skills in math. According to the data of the PISA survey in 2018, the students in Kazakh schools demonstrated lower results than in 2015 (PISA-2018). The main reasons for this decrease are as follows:

- Math teachers are not prepared enough to develop students' mathematical literacy;
- Teachers do not pay enough attention to the practical component of teaching mathematics at school (Kaskatayeva, 2019).

Considering these circumstances and believing that learning outcomes are directly dependent on the quality of education, the authors of this paper together with other scholars (Dallinger, 2017; Isaev & Shiyanov, 2005; Gabbasova, 2016) stress the necessity to reconsider the methodology of teaching mathematics at school and training pre - service math teachers in the universities to make them ready to develop students' mathematical culture.

In this study, mathematical culture is defined as a personality's integrative quality embracing a high level of fundamental mathematical knowledge and skills gained through educational activities at school and /or university. It also defines a personality's readiness to apply those knowledge and skills effectively to solve problems in life and at work. The mathematical culture includes skills of logical and abstract analysis, induction and deduction, methods of processing knowledge, data and information (Artebyakina, 2016; Ezhova, 2011; Melnikov, 2017; Nasypany, 2017).

It is believed that for raising the quality of math education at school, the pre - service

math teachers' training should focus on nurturing their psychological readiness to teach at school, developing their sound knowledge and skills of math as a subject and developing their teaching competences to use proper methods and techniques which would target students' mathematical culture and their readiness to deal with the challenges of higher education and professional development. For this purpose, it is necessary to consider all richness of math as a discipline in a unity of its tools and their applicability to solving real life problems. It is important to demonstrate all the potential of math to the students in order to make them realize the necessity to learn and develop their intrinsic motivation to acquire math knowledge and skills. Together with that it is essential to apply innovative technologies to streamline knowledge transfer and acquisition, assure effectiveness of learning and sustainability of the learning outcomes (Smyrnova-Trybulska, E. et al, 2017; Sekret, 2020).

Although, despite a wide range of research on training pre-service math teachers and developing their mathematical culture in a pedagogical university, the problem related to the preparation of pre-service math teachers for the development of the students' mathematical culture at school needs more attention from researchers and practitioners (Dallinger, 2017).

The analysis of psychological and pedagogical literature, dissertations and case studies, the authors' own teaching experience in middle and higher schools allowed to reveal a number of gaps which should be covered in order to enhance the overall level of the students' mathematical culture and their skills to apply math knowledge in their life and work. Among them are:

- Insufficient level of the students' overall mathematical literacy and a societal demand to train school graduates to use math knowledge and skills in their everyday life, a need for them to understand a connection between the school math problems and a necessity to do proper calculations in life and work;

- Lack of effective approaches and practices of training pre-service math teachers to develop students' mathematical culture at school and a societal expectation from universities to prepare pre-service teachers to meet the demands of modern school education in a view of the world's growing industrialization and technological boom.

The revealed gaps give rise to an urge of developing and implementing into the pre-service math teachers training new methods and approaches to shape their skills and competences to teach math at school, focussing on the students' mathematical culture, creating proper educational environments to meet societal expectations for the mathematical literacy and competences of school graduates.

The determined urge has a clear practical application which lies in enhancing the overall quality of the pre-service math teachers and, in its turn, the profoundness and quality of math education at school. In this way, the school graduates will become more confident to continue their

education in universities and develop their professional careers at the level of the world standards. This process is going to have a more extended value, that is enhancing the competitiveness of Kazakh education, and the quality of training specialists to be employed in companies and production of the international level.

The purpose of this research is to develop a methodology of training pre-service math teachers which would target their professional readiness to develop students' mathematical culture at school.

The purpose of the study defines its objectives as follows:

1) Discuss the concept of "mathematical culture" and clarify its structure;
2) Define the concept of "pre-service teachers' readiness to develop students' mathematical culture" and develop a theoretical model of training pre-service math teachers accordingly;
3) Implement the developed methodology in the university program of math teachers' education and test its effectiveness;
4) Define the pedagogical conditions of effective training pre-service math teachers for developing students' mathematical culture at school.

The research hypothesis of this study is as follows:

- Training pre-service math teachers should be structured and organized in such a way that the pre - service math teachers would be ready psychologically and professionally to teach math at school, equipped with sound math knowledge and skills as of their professional subject matter, be able to apply and develop proper educational techniques targeting students' mathematical culture, use innovative technologies according to the needs of the learning processes.

To reach the purpose of the study, the authors:

1) Designed a theoretical model of training pre - service math teachers, based on the literature analysis and successful case studies;
2) Developed a framework of training pre-service math teachers with the implementation of such educational technologies as modeling, development and solutions of applied, historical and educational problems, organizing and implementation of group projects, creating digital videos and new teaching materials;
3) Prepared a set of the individual assignments and guidelines for the students based on the developed methodology and the theoretical model.

After the practical testing of the designed methodology and the theoretical model, the authors shaped pedagogical conditions of effective pre - service math teachers'

training which are laid out in the conclusions of this paper.

Wilson (1990), stated that the Introduction explains the scope and objective of the study in the light of current knowledge on the subject. State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.

Literature Review

The methodological background of this research is comprised by the studies on:

- Methodology of teaching and learning (Lyashenko & Mineeva, 2018; Gravemeijer, 2017; Khutorskoy, 2016; Pound, 2011; Sekret, 2018);
- Culture and culturological approach in education (Abulkhanova, 2017; Trokhimchuk, Raevsky & Braerskaya, 2018; Bolshakov, 2018; Daniyarova, 2017; Lyashenko & Mineeva, 2018; White, 2017; Tusheva et al, 2021; Yatsenko et al, 2022);
- Mathematical culture (Artebyakina, 2016; Burton, 2009; Dmitriev, 2009; Slastenin, 2013; Slobodchikov & Isaeva, 2013; Duta & Tomoaica, 2015; Courant & Robbins, 1996; Yvette d'entremont, 2015).
- Activity-based approach in learning and psychology of activity (Johnson et al, 1998; Sekret, 2009; Noreen & Rana, 2019; Baserer, 2020);
- Competence approach in education (Duta, Tomoaicaa & Panisoara, 2015; Reutova, 2016; Sekret, 2009; Smyrnova-Trybulska, E. et al, 2018; Tarigan, Sutapa & Mochtar, 2019);
- Innovative technologies and ICT in training pre-service teachers and enhancing students' digital competences (Gabbasova, 2016; Smyrnova-Trybulska, E. et al, 2017; Sekret, 2021).

The subject of this research is the development of effective methods of preparing pre-service math teachers for the development of students' mathematical culture and shaping the teaching methodology accordingly.

Before analyzing recent case studies related to the subject of this study, it is important to define the concepts of "culture" and "mathematical culture".

Culture is often defined as a set of rules that is followed by a person or a community to practice certain ways of behavior with inherent experiences and beliefs. Culture originates in human activity, community knowledge, life styles and creativity. White (2017) believes that "culture is an internally organized system of phenomena completely dependent on symbols".

The concept of "culture" as a general philosophical term has been widely discussed in a number of research including the works by Abulkhanova (2017), Trokhimchuk, Raevsky &

Braerskaya (2018), Bolshakov (2018), Daniyarova (2017) and others.

From the point of view of acmeology, the science of professional development in the context of a personal-activity approach, the concept of "culture" is used to characterize the highest achievements in the professional sphere, as well as to denote a set of material and spiritual values created by humanity (Lyashenko & Mineeva, 2018).

The culturological approach in education is defined as a unity of three aspects - axiological, technological, and personal-creative (Kaskatayeva, 2019). The axiological aspect involves the development of a personality's values. In this respect, the learning environment of an educational establishment should become a space for developing students' culture, understanding and acquisition of values, providing opportunities for creativity, self-realization, personal and professional development.

In the case of a teacher' professional culture, it is important to highlight the components of general culture, general scientific and pedagogical components. In this way, the teacher's pedagogical culture is an indicator of the level of their methodological competence together with the personal and professional development.

To define the concept of "mathematical culture", it is important to refer to the content of mathematics as a subject and its tasks. Mathematics has always been an integral part of human culture, serving as a key to understanding the world around, the basis of scientific and technological progress, an important component of the person's intellectual development. Considering the profound importance of math in all spheres of human's life, mathematization has become an integral part of education, work and life of modern society. As Courant & Robbins (1996) defined, math is like literature, which brings human's history to life and engages a person intellectually and emotionally, opening a window into the world of data and calculations (Courant & Robbins, 1996). Mathematics is an integral component of all cultural contexts, and the meaning of all cultural contexts depends on the individual's interpretation within that culture. Taking advantage of this rich cultural experience means that students should be exposed to a variety of experiences and cultural resources. Schools can help students learn about their own culture as well as that of others by using classes that demonstrate the relationship between culture and mathematics (Yvette d'entremont, 2015). Mathematics is necessary for a person's intellectual development (Tusubekova, 2016; Reutova, 2016). Mathematics teaches, develops, and prepares students to continue their education to gain a profession or study in higher educational institutions.

The term "mathematical culture" was introduced in the 20-30s of the twentieth century. Later, some authors began to consider mathematical culture as a system of knowledge and skills. In the 1940s and 1950s, the development of mathematical

culture was considered within the theory of gradual development of mental actions. This problem was addressed by both mathematicians and teachers. In the 1980s, mathematical culture was defined not only as knowledge, skills, and their free usage, but also as the one including mathematical thinking and mathematical language (Kaskatayeva, 2019).

The studies on mathematical culture differ a lot in their methodologies and perspectives. Thus, Burton (2009) differentiated between the culture of mathematics as recognizably discipline-related (particular attitudes towards beauty, rigor, succinctness, etc.) and the mathematical culture, the socio-political attitudes, values and behaviors that constitute how mathematicians, and their students, experience mathematics in the settings of conferences, classrooms, tutorials, etc. Whereas aspects of the culture of mathematics have, historically, been defined as integral to mathematics and are seen as part of what students are expected to acquire in the process of becoming mathematicians, the mathematical culture is a product of stereotypes and biases that control who can enter the discipline and how they do so (Burton, 2009).

Nowadays there are many definitions and interpretations of mathematical culture. Thus, it is defined as:

- a complex system that arises from the interaction of cultures, reflecting various aspects of a person's mathematical development including knowledge, self-education and language culture (Artebyakina, 2016);
- an infrastructure for the perception and processing of information by means of mathematics (Melnikov, 2017);
- an integral education of the individual (Ezhova, 2011).

Nasypany (2017) refers to the most important characteristics of mathematical culture which include mathematical knowledge, skills and abilities to solve mathematical problems, the ability to transfer the acquired knowledge to new situations; capacities to act rationally and creatively.

Many studies have been discussing the problems of developing students' mathematical culture in higher educational institutions, though they differ in the methodologies applied and approaches to define the structure of mathematical culture. Thus, Melnikov, Boyarsky & Lokshin (2017) use the model of mathematical culture as an infrastructure for analyzing the processes of the information perception and its processing, information exchange, which includes phenomena, relationships, subsystems, interfaces, and control systems. Artebyakina & Kozlova (2016) study some aspects of developing students' mathematical culture in pedagogical universities during the educational process through the formulation of problems and the integration of special (mathematical), methodological and practical types of knowledge.

Speaking about a necessity to reform teaching practices and approaches in training pre-service math teachers, it is important to focus on the notion of the competence and key competences required for an effective math teacher.

Thus, Reutova (2016) stresses the importance of life-long learning and discusses key competences required for constant personal and professional development.

Khutorskoy (2016) identifies seven groups of key competencies for general education. They include value-semantic competence, general cultural competence, educational and cognitive competence, information competence, communicative competence, social and work competence, competence of personal self-improvement.

Tarigan, Sutapa & Mochtar (2019) divide teacher's competences into three components - classroom management, teacher professional development, and academic excellence.

Duta, Tomoaicaa & Panisoara (2015) identify ten most important characteristics of an effective teacher. They are professionalism, eloquence, charisma, honesty, correctness, demanding, firmness-determination, positive attitude, meekness - gentleness, and patience. Effective teachers are "people in the full sense of the word", that is, those who are characterized by "humor, honesty, empathy, more democratic than autocratic, able to make a report with students, both individually and in groups, open, spontaneous, able to adapt to changes" (Duta, Tomoaicaa & Panisoara, 2015).

The problem of preparing pre-service math teachers for the development of students' mathematical culture at school is currently of particular importance, since, according to the results of the PISA study in 2018, Kazakh school students significantly dropped in their level of knowledge. The average score of mathematical literacy of Kazakh school students in mathematics was 423 points (53rd place). This indicates that school students do not have the ability to apply mathematical knowledge and skills in non-standard situations, which are crucial for the success in higher education and professional development (PISA-2018).

According to Dallinger (2017), training math teachers need to be radically changed. The math education should be enhanced with more fundamental knowledge, and conducted in profound courses with an increased number of teaching hours, focussing on math as a subject and methodology of its teaching.

Nowadays, pedagogical universities and schools apply the following educational innovations:

- Information and communication technologies (ICTs) in subject training in order to enhance pre-service teachers' general information culture (Smyrnova-Trybulska, E. et al, 2017);
- Personal-oriented technologies of teaching by creating comfortable, conflict-free and safe learning environments;

- Monitoring of students' intellectual development;
- Implementing new educational technologies;
- Designing innovative didactic materials (Gabbasova, 2016).

There are case studies that demonstrate significant results in training pre-service math teachers and enhancing mathematical culture. They are as follows:

- Math teachers' training in the context of new state standards concerning pedagogical education and mathematical education in particular (Dalinger, 2017);
- Implementing culture in the math class of the early education in Finland and Sweden (Hemmi & Ryve, 2015).
- Applying the culturological approach to the development of the educational content in a pedagogical university for training pre-service teachers (Isaev & Shiyanov, 2005), etc.

Though, despite certain advances in this direction, the problem remains to be urgent considering the drop in the level of math literacy among school graduates mentioned above.

Therefore, based on the literature analysis and successful case studies, a theoretical model was developed to embrace the key methodologies and approaches in math education and teachers' training to enhance the quality of pre-service math teachers' training and prepare them for developing students' mathematical culture at school (Figure 1).

Research Methods

The study was conducted with the following research methods:

- Literature analysis (theoretical analysis and generalization of the recent case studies in psychology and education; analysis and generalization of the national educational practices and those from different countries in concern of teaching mathematics; analysis of the national educational standards for the higher education for training math teachers; analysis of the studies on the research problem);
- Methods of collecting data (observation; interviews; questionnaires);
- Pedagogical experiment.

Assessment methods were focused on the development of a person's mathematical culture in the pedagogical experiment via testing, self-assessment, creating a portfolio, monitoring work and describing the students' behaviors.

The pre - service math teachers' professional readiness was tested before and after the pedagogical experiment in the experimental and control group. For this purpose, the following tools were applied:

1) Students' self-assessment on the questions reflecting the essence of teaching math as a profession and a level of the pre - service math teachers'

professional training. The participants were supposed to give an oral or written answer to each question. The answers were cross-checked by the instructor. Each correct answer gave 2 points, an incomplete answer - 1 point, a wrong answer or no answer gave 0 points.

2) Psychological tests of the pre - service math teachers' communicative skills.

3) Analysis of the pre - service math teachers' professional readiness in unity of its psychological, content and practical components by the method of Shurukhina (2000).

4) The system of tasks in mathematical analysis, according to the methodology of teaching mathematics.

5) Testing of the pre - service math teachers' mathematical culture.

Pedagogical Experiment and its Procedures

The pedagogical experiment was conducted at the Kazakh National Women Teachers' Training University of Almaty City with the students of Physics and Mathematics Faculty in three stages within 2018-2020 at the courses "Mathematical analysis", "Methods of teaching mathematics" and "History of mathematics".

The experiment consisted of three phases:

- Exploratory summative,
- Development and monitoring;
- Evaluation.

The purpose of the first stage (2018-2019) was to monitor the students' activities during their learning processes. The experiment was attended by the Kazakh and Uzbek female students in the age of 20 - 22 years old.

At this stage, the students participated in tests, questionnaires and interviews designed to reveal students' learning experiences and attitudes. Together with that, different methods of training pre-service math teachers were tested to select the most effective ones, appropriate for developing students' mathematical culture in schools. The research, methods' testing and students' feedback at this stage resulted in the development of the scientific and methodological background for training pre-service math teachers for developing students' mathematical culture. Alongside with the development of the methodological background of the training, it was important to note that the students who participated in the experiment have developed an interest in mathematics as a part of universal culture.

At the second stage of the experiment (2019-2020) the following work was done:

- The authors of this study developed a theoretical model of training pre-service math teachers for developing students' mathematical culture;
- The framework of developing pre-service math teachers' main competencies was established with the implementation of such methods as modeling, compilation and solution of applied, historical and educational problems. It also

entailed organizing and implementation of group projects. A set of the individual and group assignments was developed and provided accordingly.

- Based on the developed methodology and the model designed for training pre-service math teachers, a pedagogical experiment was conducted with the undergraduate students, pre-service math teachers.

At this stage of the experiment, it was also stated that students should acquire such mathematical knowledge and practical skills that would also enhance their skills of planning, analysis, reflection, self-assessment as well as abilities to transfer theoretical knowledge into the context of the practical problems and their solutions. All together the chronological order of the students' learning activities within the pedagogical experiment can be presented as follows:

1) Enhancing the students' interest in mathematics as a part of universal culture;

2) Acquisition of the fundamental mathematical knowledge and practical skills of planning, analysis, reflection and self-assessment;

3) Application of theoretical knowledge into practice, embracing obtaining knowledge from real situations, action methods in non-standard situations, heuristic methods of solving problems, abilities to distinguish facts from speculations, application of the knowledge methods of knowledge.

At the third stage of the experiment, in the 2020-2021 academic year, the authors of the research conducted quantitative and qualitative analysis of the data, statistical and stochastic data processing, comparative data analysis, construction of charts, graphs and histograms, and generalization of the theoretical conclusions.

Results and Their Discussion

Theoretical Model of Training Pre-Service Math Teachers for Developing Students' Mathematical Culture at Schools

Modern society requires education to train a teacher who would be competent and creative, able to solve professional and social problems in accordance with the norms of the new educational paradigm and demonstrate a high professional culture. The development of mathematical culture occurs in the process of acquiring knowledge of math and skills to apply it for solving real life problems.

The analysis of definitions of mathematical culture, as well as our experience of teaching mathematics at a pedagogical university, allows us to define the mathematical culture of pre-service math teacher as an integrative quality that embraces a high level of fundamental mathematical knowledge and skills realized through educational activities, psychological and cultural potential, key competencies and skills of implementing innovative technologies.

The concept of "the pre - service math teachers' mathematical culture" included the following features:

1) Symbiosis of the main principles of the the cultural, activity and competence approaches;
2) Specifics of teaching math as a profession.

In this context, the pre-service teachers' readiness to develop students' mathematical culture at school is defined as:

- an integrative quality embracing professional education, knowledge of the content and psychological component which all together chanalize into a professional ability to create learning conditions which would lead students to the successful acquisition of the mathematical knowledge and skills,

and includes:

- an ability to solve applied problems based on the common values of human culture,
- competences to apply innovative technologies according to the learning requirements;
- a clearly articulated need and openness for life-long learning, professional development to master professional skills and creativity, independence, flexibility and responsiveness to the students' psychological features and their learning needs.

Based on the analysis of the literature on the methodology of teaching math, recent case studies in psychology and education, national educational practices and those from abroad, national educational standards for the higher education for training math teachers and other related studies, we have developed a theoretical model of training pre - service math teachers for the development of the students' mathematical culture at school (Figure 1). The model includes a goal, objectives, principles, conditions, components of the structure of mathematical culture, methodological approaches, methods, forms and technologies of training pre-service math teachers, joint creative activities of the teacher and students, learning outcomes.

The Process of Training Pre - Service Math Teachers for the Development of Students' Mathematical Culture at Schools

Goal	Tasks	Principles	Conditions

Components of Mathematical Culture ↓

↔

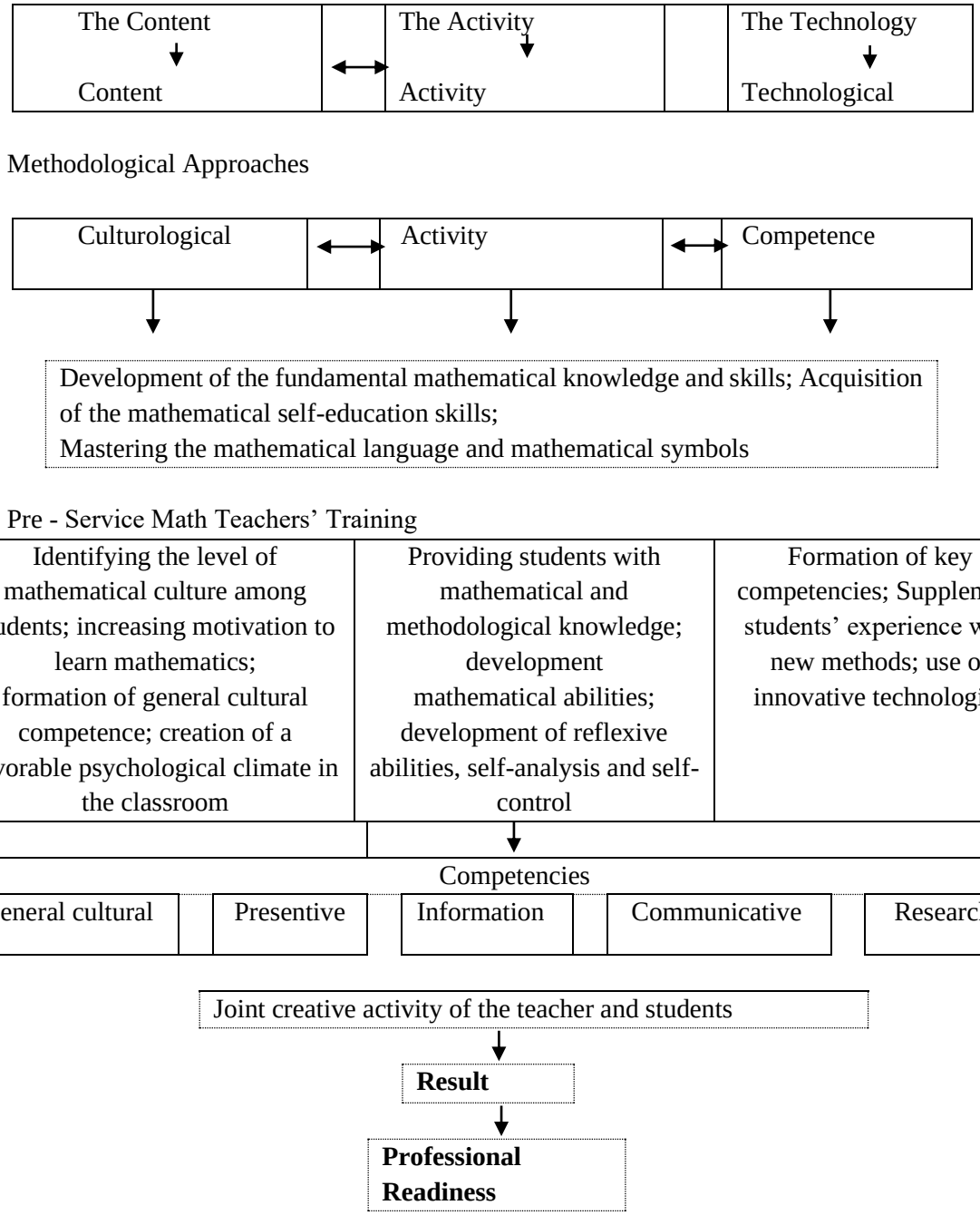

Figure 1. Theoretical Model of Training Pre-Service Math Teachers for the Development of Students' Mathematical Culture at School

In the development of the model, we relied on the principles of humanization, democratization, differentiation and individualization recommended by Slastenin (2013). The humanization of the

educational process is defined as a process that creates favorable conditions for a personality's development within the education system.

The principle of differentiation characterizes "personality-oriented learning, which includes different levels of learning, based on the current state of the student's psychological and educational readiness, their goals, possibilities and other factors" (Slastenin, 2013).

The principle of democratization assumes provision of the students with opportunities for freedoms of choices, self-development, self-regulation, self-determination and self-education (Shilova, 2017).

The model is also based on the following methodological approaches: 1) Culturological approach, 2) Activity-based approach, and 3) Competence approach.

1) In this research, the culturological approach is defined as a purposeful, scientifically based, teacher-organized ascent to the culture of modern society (Dmitrieva, 2009). The teacher introduces the concept of culture and develops the education process guided by the notions and principles of the culture where the students and the education are grounded. In this way, they learn to live within the culture, acquiring its values and main notions. As Abulkhanova states (2017), the personal and creative aspect of the culturological approach is determined by the relations of the individual and culture. A person is a carrier of culture. Culture develops the existential essence of a person on the one hand, and on the other one, a person becomes a creator themselves adding to the cultural context with their work, personal creativity and self-realization. These reciprocal relations become the subject of historical and cultural creativity. Culture should be considered not only from the point of view of the local customs and traditions but from the perspectives of the global human values which include moral awareness, morality, knowledge of the universal historical and cultural values.
2) In the context of this study, the activity-based approach is interpreted as an educational paradigm of organizing teaching and learning activities based on the notion of activity itself, psychological features of its duration and fulfillment as well as the psychology of a doer involved in this activity. The activity-based approach refers to the key competences; methods of processing scientific knowledge (analysis, synthesis, analogy, comparison, induction, deduction, observation, experiment); considers the

structure of the educational process from the point of view of its purposefulness as any kind of activity i.e. its orientation to the goals; includes abilities to evaluate the work done (reflection and self-evaluation); abilities to learn and acquire knowledge independently; analyze information resources; skills and abilities to set a task / goal, analyze it with the application of the mathematical logic apparatus and modern technologies. In concern of the training pre-service math teachers, everything described above should be developed in such a way that the graduated teachers would be able to transfer the above mentioned skills to their students while teaching mathematics.

3) Competence approach is based on the fundamental separation of competencies as attributes of the external and internal worlds of a person. Competence is a social requirement (external norm) which is expected to be developed in the context of educational activities (Khutorskoy, 2016). In terms of the activity-based approach, competence should become a goal of education as an activity, and all its sub-activities should be purposefully organized to reach this goal.

Each approach includes three interrelated components:

- Acquisition of the fundamental mathematical knowledge and skills;
- Developing skills of self-education in math;
- Mastering the mathematical language.

The main conditions for training pre-service teachers for the development of the students' mathematical abilities are represented in the following blocks:

- Psychological preparation,
- Content (math knowledge and skills),
- Practical training (teaching skills).

The structure of the mathematical culture of the pre-service math teachers is represented by the unity of content, activity, and technological components:

- The content component covers the body of knowledge in the field of math, psychology and education. It also presupposes mathematical literacy.
- The activity component derives from the activity-based approach and considers the key competencies, methods of acquiring and processing scientific knowledge, structuring the educational process according to its purpose, abilities of reflection and self-evaluation, capacities to transfer the acquired knowledge into new settings; abilities to be flexible and creative while operating with the

mathematical tools for solving a problem; capacities to predict the results of actions and assess their effectiveness beforehand.

- The technological component entails competences and skills to apply innovative technologies in teaching mathematics according to the needs of the educational process.

Considering different studies concerning teachers' competences (Khutorskoy (2016), Reutova (2016), Tarigan, Sutapa & Mochtar (2019), etc), we have identified key competencies required for a math teacher and provided their descriptions. They include general cultural competence, mathematical, methodological, informational, communicative, and research competencies:

1. Students' general cultural competence is defined as an ability to act and behave in the surrounding social environment according to moral norms and master value foundations of common human culture, their readiness for the continuous development of their professional qualities, creativity and independence.
2. Mathematical competence or competence in the subject of the pre-service teachers' profession is knowledge in the field of mathematics and methods of its teaching. It includes math knowledge and skills, abilities to model, understand math rules and notions, students' understanding of their own abilities and capacities, skills of analysis, reflection, and self-assessment of the educational and cognitive activities.
3. Methodological competence implies the pre-service math teachers' readiness to teach mathematics at school using modern pedagogical teaching technologies, an ability to continuously develop professional and personal qualities.
4. Information competence is the pre - service math teachers' readiness and abilities to use information technologies for their personal and professional purposes, being critical thinkers in their evaluation of the information sources and the information's quality.
5. Communicative competence is the pre - service math teachers' abilities to communicate in person and remotely, skills to work in a group, resolve conflicts in real life situations, knowledge of necessary languages and techniques for effective communication, laws and rules of communication determined by the cultural norms and global human values.
6. Research competence is a crucial component of the professional

> profile of a math teacher who is knowledgeable about research methodology, skillful in designing research, able to select research methods and tools, conduct an active research independently and in a research group (Kaskatayeva, 2019).

We believe that students should be aware of the competencies required to be able to teach at school. This knowledge is helpful for them to evaluate their own learning, reflect on the educational processes and their progress.

Pedagogical Experiment and Learning Outcomes

To develop students' mathematical culture at school, it is necessary to provide special training to the pre - service math teachers for them to be aware of the content of mathematical culture, societal needs and their own readiness to develop appropriate knowledge and skills among the students at school.

The pedagogical experiment was planned and designed according to the theoretical model, designed by the authors of this study based on the literature review and their own practical experience.

On the basis of the model, the framework of developing pre-service math teachers' main competencies was established with the implementation of such innovative technologies as modeling, compilation and solution of applied, historical and educational problems. It also entailed organizing and implementation of group projects. A set of individual homework assignments and guidelines for pre-service math teachers was designed accordingly and implemented during the pedagogical experiment. Based on the model and following the framework, the practical and seminar classes of the mathematical courses were organized in such a way that the students acquired mathematical knowledge and practical skills of planning, analysis, reflection and self-assessment, experience of applying theory into practice and solving practical methodological problems.

For example, the students' general cultural competence at seminars of the course "History of Mathematics" was developed by making a shift from the teacher-centered paradigm of learning to the student-centeredness. Thus, in the traditional practice of the seminars, the teacher introduces the students into the program material, provides necessary information, motivates and guides the students until they are ready to work independently. Unlike traditional practices, in the context of the pedagogical experiment, we worked to stimulate students' learning independence and creativity from the very beginning. The students were required to:

- Search for historical facts and information;
- Solve historical problems and problems of the mathematical culture development;
- Prepare didactic materials on the history of mathematics;
- Apply the content and tools of mathematics in a view of its history.

Considering History of Mathematics as a subject, it is important to note that it is a rich source to use for developing students' skills to compare, discuss, solve problems, think logically, use facts to illustrate theory, induct and deduct based on the facts and statements. Implementation history and its materials is crucial for developing students' general culture and encouraging them to learn. At the seminars on History of Mathematics the undergraduate students received the following tasks to fulfill after each topic:

1. Prepare a short story according to the level of the school students. The story should reflect ideas and achievements in Science of that period as well as describe the problems faced in that time;

2. Design five problems based on the historical facts and provide their solutions. Develop at least five assignments on logical thinking, quizzes or puzzles.

Once a term, the students were required to prepare a summary on a given subject. They were expected to provide a concise overview, containing statements which would focus on the main idea and content of the subject. The summary should be presented in the form of a 5-minute talk accompanied with a question-answer session.

The specifics of solving a math problem based on the historical materials entails inductive and deductive reasoning, logical thinking, imagination, appealing to the facts, reality, factual needs and possible solutions. Referring to historical facts and applying math knowledge brings theory and practice together as well as help students see how math works for the needs of the human and should be used for solving real life problems.

During the seminars, the students presented the assignments they designed, solved the problems presented by their peers and discussed the application of this knowledge to the content of modern life.

For example, the students discussed and solved together a math problem from "Mathematics in Nine Books". The math problem concerned buying a chicken, "If everyone contributes 9 (monetary units), 11 will remain. But if everyone contributes 6, then 16 will not be enough. Find out the number of people and the cost of the chicken".

Solution: "Let there be x people, then with a contribution of 9 monetary units, the value of the chicken will be 9x-11, and with a contribution of 6, the value of the chicken can be determined as follows: 6x + 16. That is, 9x - 11 = 6x + 16. Hence, x = 9, then the cost of the chicken is 6x + 16 = 70".

The students participating in the pedagogical experiment completed a project on the topic: "Development of Applied Math Problems as a Means of Enhancing Students' Mathematical Literacy". The implementation of the project helped students to acquire skills and knowledge directly from reality. They were: 1) applied math problems; 2) problems similar to the given; 3) its inversion; 4) assignments based on a given scheme, equation, or a numerical expression.

Here are some examples of the assignments, designed to develop students' skills to compose tasks similar to the data:

1) Aidana bought 2.5 kg of chocolates "Bear in the North" at a price of 2800 tenge per 1 kg. How much did she pay? Come up with a similar math problem.

2) The side of the square is 0.7 m. Calculate its area. Come up with a similar math problem.

In this way, the students were able to develop their skills to reproduce things following the model, create assignments by themselves, enhance their research capacities in order to establish a connection between math and real life problems to solve.

In concern of the communicative competence, at the practical classes of the course "Methods of Teaching Mathematics", the students learned to:

- Be fluent in mathematical language;
- Communicate with peers (work in groups), with a teacher, use professional terms and language, participate in conversations and discussions;
- Be able to express own thoughts and ideas, formulate definitions, statements and prove ideas;
- Develop assignments;
- Prepare and conduct lessons, develop appropriate visual aids and presentations;
- Be able to evaluate their own activities, reflect on the processes and results;
- Speak in public and present reports, etc.

Another innovative element of the pedagogical experiment was designing lectures on the principles of the problem method and with the application of digital technologies.

The educational provision of the courses "Methods of Teaching Mathematics" and "History of Mathematics" contained full texts of all lectures, tasks for SIW (Students' Independent Work) and SIWT (Students' Independent Work with a Teacher). The courses were also equipped with necessary digital educational materials, video and audio tapes. Concerning high demands for the teachers' digital competences, it is of special importance to develop pre - service math teachers' skills and competences not only to be able to perceive the information from digital sources but to use digital technology tools for creating new contents and assignments for their students and enhancing their mathematical culture.

One of the most relevant and effective teaching tools is video tutorials, which make the training sessions more interesting, dynamic and convincing. Implementation of the digital tutorials makes huge flows of information more accessible, understandable and retainable in memory. Teachers' skills to design video tutorials facilitate teaching and learning in many aspects, making educational material visual and more powerful in terms of its remembering. Accessibility of the digital tutorial for the students anytime and from any place

essures a way to their independence in learning. Besides, the tutorials can be used for developing e-learning and distance education for math and math teaching.

The students were required to get ready before each class. For example, for a practical lesson on the topic: “Teaching Mathematics through Problems” each student had in their notebooks 21problems solved. Out of them, 7 were of high difficulty, 7 of medium level and 7 of the entry level. The students were also supposed to present the solution of at least one problem of high difficulty. At the class, the students analyzed completed assignments. One student was making a demonstration of the problem solution in front of the class, while other students were actively participating in its discussion and analysis.

At the beginning and at the end of the experiment, the students participated in the questionnaire and tests to determine their level of readiness to develop students' mathematical culture. The results are represented in Table 1.

Table 1. The Level of the Pre-service Teachers Readiness to Develop Students’ Mathematical Culture before and after Pedagogical Experiment

Training	Before the experiment				After the experiment			
	Experimental group		Control group		Experimental group		Control group	
	Students, N	% qualities	Students, N	% qualities	Students, N	% qualities	Students, N	% qualities
Psychological	225	53,3	197	51,7	217	85,2	185	63,7
Content (mathematics)	225	64,4	197	66	217	87,5	185	65,9
Practical (teaching skills)	225	38,2	197	36,5	217	86,1	185	60

The data were also represented in the diagram to show the difference in the level of the pre-service teachers’ readiness before the pedagogical experiment and after it. The data were also contrasted with the results from the control group that continued their education in a traditional way (Figure 2).

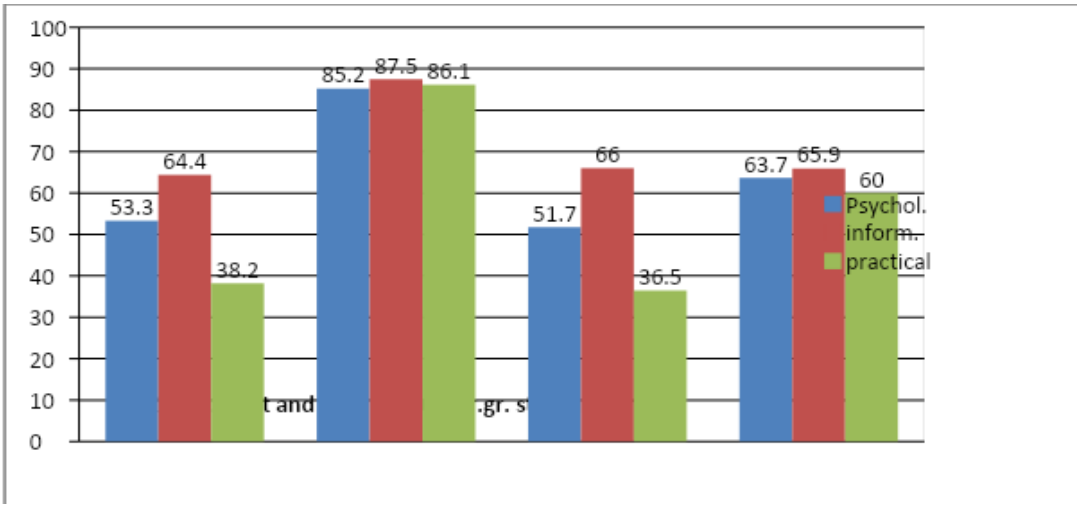

Figure 2. The Level of the Pre-service Teachers Readiness to Develop Students' Mathematical Culture before and after Pedagogical Experiment

By the end of the pedagogical experiment, the pre - service math teachers' level of psychological readiness in the experimental group increased by 29.9%, and in the control group by 12%. The pre - service math teachers' level within the content component increased by 23.1% in the experimental group, and remained almost the same in the control group. The level of practical readiness concerning math teaching increased by 47.9% in the experimental group and by 23.5% in the control group.

Due to the limited volume of the article, it presents the statistical analysis of the data on the content component of the pre - service math teachers' readiness in the control and experimental groups as evidence of statistically significant difference in the results obtained.

To do this, out of a total of 225 people (five groups), two groups were selected with the same number of students (24 people each). We used Student's t-test for independent variables. A 10-point system was used. The table indicated the averages ($\overline{X}$), standard deviations (d), sample size (n), dispersion (δ^2) in determining the significance of differences.

Table 2. Data Analysis of the Control and Experimental Group

n	Control group (CG)	Experimental Group (EG)	CG	EG	CG	EG	CG	EG	Calculations
			$\underline{M_1}$	$\underline{M_2}$	d_1	d_2	d_1^2	d_2^2	
1	7	10	5,6	8,7	1,4	1,3	1,89	1,78	

2	7	10	5,6	8,7	1,4	1,3	1,89	1,78	$\underline{M_1} = \frac{135}{24} = 5,6$
3	5	9	5,6	8,7	-0,6	0,3	0,39	0,11	$\underline{M_2} = \frac{208}{24} = 8,7$
4	6	10	5,6	8,7	0,4	1,3	0,14	1,78	
5	4	8	5,6	8,7	-1,6	-0,7	2,64	0,44	$\sigma_1^2 = \frac{29,63}{24-1} = 1,29$
6	5	9	5,6	8,7	-0,6	0,3	0,39	0,11	
7	4	10	5,6	8,7	-1,6	1,3	2,64	1,78	$\sigma_2^2 = \frac{25,33}{24-1} = 1,1$
8	4	7	5,6	8,7	-1,6	-1,7	2,64	2,78	
9	5	8	5,6	8,7	-0,6	-0,7	0,39	0,44	
10	6	8	5,6	8,7	0,4	-0,7	0,14	0,44	
11	7	8	5,6	8,7	1,4	-0,7	1,89	0,44	
12	6	9	5,6	8,7	0,4	0,3	0,14	0,11	
13	5	10	5,6	8,7	-0,6	1,3	0,39	1,78	
14	4	9	5,6	8,7	-1,6	0,3	2,64	0,11	
15	5	7	5,6	8,7	-0,6	-1,7	0,39	2,78	
16	6	7	5,6	8,7	0,4	-1,7	0,14	2,78	
17	7	8	5,6	8,7	1,4	-0,7	1,89	0,44	
18	5	8	5,6	8,7	-0,6	-0,7	0,39	0,44	
19	5	8	5,6	8,7	-0,6	-0,7	0,39	0,44	
20	6	8	5,6	8,7	0,4	-0,7	0,14	0,44	
21	5	9	5,6	8,7	-0,6	0,3	0,39	0,11	
22	7	10	5,6	8,7	1,4	1,3	1,89	1,78	
23	8	10	5,6	8,7	2,4	1,3	5,64	1,78	
24	6	8	5,6	8,7	0,4	-0,7	0,14	0,44	
Σ	135	208					29,63	25,33	

1. Based on the results obtained, the values of the arithmetic mean were calculated using the formula (1):

$$M = \frac{\sum_{i=1}^{n} |X_i|}{n}$$, where n=24 (1)

Dispersion: $\delta^2 = \frac{\sum_{i=1}^{n} (X_i - M)^2}{n-1}$ (2)

Average deviation $d = X_i - \underline{M_1}$ $d^2 = \left(X_i - \underline{M_1}\right)^2$ (3)

2. Table 3 represents the data to determine and evaluate the reliability of the

differences with the parameters for the calculation.

Table 3. Parameters To Calculate

	Control group	Experimental group
n	24	24
$\underline{M}$	5,6	8,7
σ^2	1,29	1,1

Checking hypotheses H_0 and H_1.

1) H_0: there are no changes between the levels of the professional readiness at the end of the pedagogical experiment among the pre - service math teachers of the control and experimental group.

2) H_1: there are changes between the levels of the professional readiness at the end of the pedagogical experiment among the pre - service math teachers of the control and experimental group.

3. We calculate the value of the t-test and compare the obtained value with the table value at the selected significance level (P=0.05) and the number of degrees of freedom:

$$f = (n_1 + n_2) - 2. \quad (4)$$

$$t = \frac{\left|\underline{M}_1 - \underline{M}_2\right|}{\sqrt{\frac{\sigma_1^2}{n} + \frac{\sigma_2^2}{n}}} \quad (5)$$

$$t = \frac{|5,6-8,7|}{\sqrt{\frac{1,29}{24}+\frac{1,1}{24}}} = \frac{3,1}{0,31} = 10. \qquad f = (24 + 24) - 2 = 46$$

Table values of Student's t-criterion critical values are presented in Table 4.

Table 4. Critical Values

f	p=0,1	p=0,05	p=0,01
46	1,679	2,013	2,687

4. $t_{эмп}=10>t_{кр}=2,687$ ($p\leq0,01$)$\rightarrow H_1$

Since the obtained value is bigger than the table value (10>2.687), it means that there is a significant difference in the increase in the estimates (Kuteinikov, 2008, p. 91). In other words, it means that the difference of the pre - service math teachers' professional readiness before and after the pedagogical experiment is significant, proving the effectiveness of the elaborated and implemented training based on the theoretical model, developed by the authors.

Conclusions

The conducted research concerned the issue of training pre-service math teachers to make them ready for the development of the students' mathematical culture at school.

For this purpose, the authors conducted theoretical and practical research, including the pedagogical experiment, to define effective educational conditions to prepare the pre - service math teachers for the demands of the modern school education and societal expectations put forward to the high school students when they enter higher education and decide on their further professional choices.

In the context of the study, the authors developed a theoretical model of training pre-service math teachers for developing students' mathematical culture. Based on the model designed, the framework of developing pre-service math teachers' main competencies was established with the implementation of such innovative technologies as modeling, compilation and solution of applied, historical and educational problems, implementation of group projects. For conducting the pedagogical experiment, a set of the individual homework assignments together with the guidelines for the students were developed accordingly and implemented into the practice.

The data obtained from the experiential and control groups of the pre - service math teachers taken before and after the pedagogical experiment proved a significant difference in the level of the pre - service math teachers' readiness. Contrasting the data received from the experimental group with the control group's data gives a reason to state that the significant difference in the levels of the students' readiness is a result of the implementation of the methodology developed within this study. It is also important to note that the pre - service math teachers, who joined the pedagogical experiment enhanced significantly their level of the professional readiness to develop students' mathematical culture at school in the unity of three main components, psychological readiness, math knowledge and skills, teaching competences.

Based on the literature analysis conducted, the theoretical model developed and implemented through the educational framework and a set of assignments designed accordingly, together with the results from the pedagogical experiment, it can be stated that the following educational conditions are effective for training pre-service math teachers and enhancing their readiness to

develop students' mathematical culture at school:

1. The educational process must be based on the principles of the culturological approach in unity with the activity-based approach and competence approach.
2. Pre - servive math teachers should be aware of the requirements and calls of the modern school and societal requirements, they must understand which competences they are required to develop and work purposefully to reach their educational goals and get ready to undertake responsibility for their own learning and learning outcomes of their students at school.
3. Students should acquire such mathematical knowledge and practical skills that would also enhance their skills of planning, analysis, reflection, self-assessment as well as abilities to transfer theoretical knowledge into the context of the practical problems and their solutions.
4. Development of the competences in math must be organized as bridged with the problems of real life and social community at a certain period of time. In this sense, establishing a link between theoretical knowledge and real problems which humanity has been facing at different periods of their historical development, is helpful to turn theory into practice, develop creative and critical thinking, turn the students into problem-solvers, able to cope with current problems in their lives, community and profession.
5. Innovative technologies must become a driving force in the educational and training processes, developing pre - service math teachers' own competences to apply innovative technologies for their own education and as tools to teach their students at school, enhancing their mathematical culture in the unity of content, activity, technology.

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