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## DIGITAL EDUCATIONAL RESOURCES IN INCLUSIVE MATHEMATICS TEACHING

### *Abstract*

The study examines the potential of digital educational resources for mathematics teaching in inclusive education and the readiness of pre-service mathematics teachers to integrate these resources into their professional practice. The research was conducted at O. Zhanibekov South Kazakhstan Pedagogical University. The methodological design combines a questionnaire with practice-oriented mathematical tasks. GeoGebra and Desmos were incorporated into the practical component to assess participants' ability to visualize mathematical content, use digital tools purposefully, adapt mathematical tasks to inclusive learning requirements, and differentiate activities according to learners' educational needs. The practical tasks were evaluated using five criteria: mathematical accuracy, effective use of digital tools, visualization, inclusive adaptation, and task differentiation. The methodological framework therefore approaches digital competence not merely as technical proficiency but as the ability to integrate technology with mathematical content and inclusive pedagogical practices. The practical significance of the study lies in its potential contribution to mathematics teacher education by supporting the development of learning activities that integrate digital competence with the capacity to design accessible and differentiated mathematics instruction.

**Keywords:** inclusive education, mathematics teaching, digital educational resources, GeoGebra, Desmos, pre-service mathematics teachers, digital competence.

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**ИНКЛЮЗИВТІ МАТЕМАТИКАНЫ ОҚЫТУДАҒЫ ЦИФРЛЫҚ БІЛІМ БЕРУ РЕСУРСТАРЫ**

### *Аңдатпа*

Зерттеу инклюзивті білім беру жағдайында математиканы оқытуда цифрлық білім беру ресурстарын қолдану мүмкіндіктерін және болашақ математика мұғалімдерінің оларды кәсіби қызметте пайдалануға даярлығын зерттеуге бағытталған. Зерттеу Өзбекәлі Жәнібеков атындағы Оңтүстік Қазақстан педагогикалық университетінің базасында ұйымдастырылды. Зерттеу әдістемесі сауалнама мен практикалық математикалық тапсырмаларды кешенді қолдануға негізделді. Практикалық бөлімде GeoGebra және Desmos цифрлық орталары қолданылып, қатысушылардың математикалық мазмұнды визуализациялау, цифрлық құралдарды пайдалану, тапсырмаларды инклюзивті білім беру талаптарына бейімдеу және даралау қабілеттері бағаланды. Практикалық жұмыстар математикалық дұрыстық, цифрлық құралды пайдалану, визуализация, инклюзивті бейімдеу және тапсырмаларды даралау критерийлері бойынша талданды. Зерттеудің әдістемелік негізі цифрлық технологияларды техникалық меңгеруді ғана емес, оларды математикалық мазмұнмен және инклюзивті педагогикалық міндеттермен кіріктіре қолдануды қарастырады. Зерттеу нәтижелерінің практикалық маңызы болашақ математика мұғалімдерін даярлау бағдарламаларында цифрлық және инклюзивті құзыреттіліктерді өзара байланысты қалыптастыруға бағытталған практикалық тапсырмаларды жетілдіру мүмкіндігімен анықталады.

**Түйін сөздер:** инклюзивті білім беру, математиканы оқыту, цифрлық білім беру ресурстары, GeoGebra, Desmos, болашақ математика мұғалімдері, цифрлық құзыреттілік.

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## ЦИФРОВЫЕ ОБРАЗОВАТЕЛЬНЫЕ РЕСУРСЫ В ИНКЛЮЗИВНОМ ОБУЧЕНИИ МАТЕМАТИКЕ

### Аннотация

Исследование направлено на изучение возможностей применения цифровых образовательных ресурсов при обучении математике в условиях инклюзивного образования и готовности будущих учителей математики к их использованию в профессиональной деятельности. Исследование организовано на базе Южно-Казахстанского педагогического университета имени О.Жанибекова. Методология исследования основана на комплексном применении анкетирования и практических математических заданий. В практической части использовались цифровые среды GeoGebra и Desmos, посредством которых оценивались способности участников визуализировать математическое содержание, использовать цифровые инструменты, адаптировать задания к требованиям инклюзивного образования и осуществлять их индивидуализацию. Практические работы анализировались по критериям математической корректности, использования цифрового инструмента, визуализации, инклюзивной адаптации и индивидуализации заданий. Методологический подход исследования предусматривает не только техническое освоение цифровых технологий, но и их интеграцию с математическим содержанием и задачами инклюзивной педагогики. Практическая значимость исследования определяется возможностью совершенствования подготовки будущих учителей математики посредством включения заданий, направленных на взаимосвязанное формирование цифровых и инклюзивных компетенций.

**Ключевые слова:** инклюзивное образование, обучение математике, цифровые образовательные ресурсы, GeoGebra, Desmos, будущие учителя математики, цифровая компетентность.

### Introduction

The ongoing digital transformation of education requires not only the renewal of instructional content and teaching methods but also the development of accessible learning environments that accommodate learners' individual abilities and diverse educational needs. This requirement becomes particularly important in inclusive education, where meaningful inclusion extends beyond the physical presence of a learner in a mainstream classroom. It also involves ensuring access to learning materials, active participation in educational activities, and appropriate pedagogical support. Contemporary research on inclusive mathematics education therefore emphasizes accessibility and meaningful participation as essential conditions for equitable learning opportunities [1].

The implementation of inclusive approaches in mathematics education presents specific pedagogical challenges. Mathematics requires learners to understand abstract concepts, process symbolic information, identify logical relationships, and follow sequential procedures when solving problems. These characteristics may create additional barriers for students who experience difficulties in processing information, maintaining attention, understanding abstract representations, or completing multistep tasks. Consequently, the effectiveness of inclusive mathematics instruction depends not only on the mathematical content itself but also on how this content is represented, structured, differentiated, and adapted to learners' individual needs. Previous research indicates that effective inclusive mathematics education is closely associated with flexible instructional practices, appropriate teacher support, and the creation of accessible learning environments [2].

Digital educational resources provide considerable opportunities to address these challenges. They enable mathematical information to be represented through textual, graphical, visual, and interactive formats and allow teachers to modify the complexity of tasks, organize repeated practice, and provide timely feedback. Digital technologies can also facilitate differentiated instruction by allowing mathematical content to be presented in multiple ways and adjusted to different levels of learner readiness. From an inclusive perspective, these characteristics are particularly relevant because accessibility cannot be reduced to simplifying mathematical content; rather, it requires creating alternative pathways through which learners can engage with and understand mathematical ideas [3].

Dynamic mathematics environments have particular potential in this context. Tools such as GeoGebra and Desmos allow mathematical relationships to be represented dynamically and enable learners to observe changes in graphs, parameters, geometric objects, and algebraic expressions. Such environments can support the transition between symbolic and visual representations and make abstract mathematical relationships more observable. Research on technology-enhanced mathematics education has demonstrated the potential of dynamic mathematical environments to support conceptual understanding, visualization, and active engagement with mathematical content [4, 5]. At the same time, the educational value of these tools depends substantially on how teachers integrate them into instructional activities rather than on the availability of technology itself.

This issue places new demands on the professional preparation of future mathematics teachers. Digital competence in mathematics education involves more than the ability to operate a particular application or online platform. A future teacher should be able to select a digital resource according to a specific mathematical objective, design meaningful learning activities, visualize mathematical relationships, differentiate tasks, and adapt digital materials to learners with different educational needs. This understanding is consistent with approaches that integrate technological, pedagogical, and content knowledge in teacher education [6]. Recent studies involving pre-service mathematics teachers have similarly shown that effective adoption of GeoGebra is associated with pedagogical and technological knowledge, perceived usefulness, and the capacity to incorporate digital tools meaningfully into future teaching practice [7].

The inclusive dimension adds another layer to this professional competence. A mathematically correct digital task is not necessarily an accessible or inclusive task. For example, an accurately constructed function graph may still be difficult for a learner to interpret if instructions are overly complex, the activity contains too many simultaneous operations, or no differentiated support is provided. Future mathematics teachers therefore need experience in transforming standard mathematical tasks into accessible learning activities through step-by-step instructions, visual support, differentiated levels of complexity, and alternative forms of interaction with mathematical content. Studies of teacher preparation for inclusive mathematics education emphasize that beliefs, self-efficacy, and professional competence related to inclusion can be developed through purposeful teacher education rather than being regarded as automatically acquired general teaching skills [8].

Despite the growing body of research on digital technologies in mathematics education and the increasing attention paid to inclusive mathematics teaching, these two areas are still frequently examined separately. Studies of digital mathematics environments often focus on mathematical achievement, visualization, technology acceptance, or technological pedagogical content knowledge, whereas research on inclusive mathematics education primarily addresses accessibility, participation, differentiation, teacher beliefs, and support for diverse learners [2, 7–9]. Consequently, there remains a need to examine future mathematics teachers' digital competence together with their ability to adapt technology-supported mathematical tasks to inclusive educational requirements.

This study addresses this gap by considering digital and inclusive competence within a common practice-oriented framework. In addition to examining pre-service mathematics teachers' experiences and perceptions regarding digital educational resources, the study evaluates their performance in GeoGebra- and Desmos-based mathematical tasks. Particular attention is given to mathematical accuracy, the purposeful use of digital tools, visualization, inclusive adaptation, and task differentiation. This approach makes it possible to consider not only how future teachers evaluate their own readiness but also how this readiness is manifested when they are required to design and adapt mathematical learning activities.

Accordingly, the aim of the study is to examine pre-service mathematics teachers' readiness to use digital educational resources in inclusive mathematics teaching and to evaluate their ability to integrate mathematical content, digital tools, and inclusive instructional strategies in practice.

The study is guided by the following research question: *To what extent are pre-service mathematics teachers prepared to use digital educational resources for the visualization, adaptation, and differentiation of mathematical tasks in inclusive education?*

The research hypothesis assumes that pre-service mathematics teachers demonstrate stronger performance in the mathematical and visualization aspects of digital tasks than in their inclusive adaptation and differentiation, indicating a need for more systematic integration of digital and inclusive competencies within mathematics teacher education.

### Research methodology

The study employed a quantitative descriptive research design to examine pre-service mathematics teachers' readiness to use digital educational resources in inclusive education. Data were collected through a questionnaire and a set of practice-oriented tasks involving digital mathematics tools. This combined approach made it possible to relate participants' self-reported perceptions of the potential of digital resources to their actual performance in representing mathematical content in digital environments and adapting mathematical tasks to the requirements of inclusive teaching.

**Research Setting and Participants.** The study was conducted at O. Zhanibekov South Kazakhstan Pedagogical University. The participants were students enrolled in educational programs for the preparation of future mathematics teachers. Participant selection took into account their engagement with mathematics-related courses, familiarity with digital educational resources, and preparation for future professional teaching practice.

Participation in the study was voluntary. The participants were informed about the purpose of the research and that the collected data would be used exclusively for scientific purposes. The confidentiality of personal information was maintained throughout the study, and the data were processed and reported in aggregated form.

**Research Instruments.** Empirical data were collected using two interrelated instruments: an author-developed questionnaire and a set of practical mathematical tasks. The author-developed questionnaire consisted of 20 items organized into five thematic sections: participants' general information; experience in using digital resources for mathematics teaching; perceptions of the didactic potential of digital tools; opportunities for using digital resources in inclusive mathematics education; and readiness to use these resources, including perceived barriers to their implementation. A five-point Likert scale was used to assess the main statements: 1 – strongly disagree; 2 – disagree; 3 – neither agree nor disagree; 4 – agree; 5 – strongly agree. In addition, the questionnaire examined the frequency with which participants used digital educational resources, the platforms they employed, and their overall self-reported readiness to integrate digital tools into inclusive mathematics teaching. To complement the questionnaire data with performance-based evidence, participants completed two practical tasks using the *GeoGebra* and *Desmos* digital mathematics environments.

**Practical Mathematical Tasks.** The first practical task focused on the visualization of a quadratic function. Participants were given the function

$$y=x^2-4x+3$$

and were asked to construct its graph in GeoGebra and determine the vertex of the parabola, its axis of symmetry, and its points of intersection with the coordinate axes. In the subsequent stage, the pre-service teachers were required to adapt the original mathematical task for a learner with special educational needs. The adaptation involved dividing the task into a clear sequence of steps, incorporating visual supports, providing accessible instructions, and using the features of the digital environment to support the learner's engagement with the task.

The second practical task examined the effect of a parameter on the graph of a quadratic function. Using Desmos, participants constructed the function

$$y=ax^2$$

and compared changes in the graph for  $a=0.5$ ,  $a=1$ ,  $a=2$ , and  $a=-1$ . They were asked to explain how changes in the parameter affected the orientation and shape of the parabola and to design an interactive mathematical activity for learners based on the resulting visualization. Participants were also required to adapt the activity for an inclusive classroom by developing at least two levels of difficulty.

The practical tasks were designed to assess not only the mathematical accuracy of participants' work but also their ability to use digital tools for didactic purposes and to adapt mathematical activities to learners' individual educational needs.

*Assessment of Practical Tasks.* The participants' work was evaluated according to five criteria: mathematical accuracy, use of digital tools, visualization of mathematical content, inclusive adaptation, and task differentiation. The assessment criteria and scoring descriptors are presented in Table 1.

Table 1. Assessment Criteria for the Practical Tasks

| Criterion             | 0 points                                 | 1 point                                 | 2 points                                                             |
|-----------------------|------------------------------------------|-----------------------------------------|----------------------------------------------------------------------|
| Mathematical accuracy | The solution contains significant errors | Partially correct                       | Fully correct                                                        |
| Use of digital tools  | Not used                                 | Digital features are partially utilized | Digital features are used effectively and purposefully               |
| Visualization         | No visualization is provided             | Basic visualization is provided         | Purposeful visualization clearly represents the mathematical content |
| Inclusive adaptation  | No adaptation is provided                | Individual elements are adapted         | Systematically adapted to meet the learner's educational needs       |
| Task differentiation  | Not provided                             | Partially addressed                     | Provided at two or more levels of difficulty                         |

The maximum score for each criterion was 2 points. Thus, the total score for the practical tasks ranged from 0 to 10 points. For descriptive purposes, the results were classified into three levels: 0–3 points as low, 4–7 points as moderate, and 8–10 points as high. The study was conducted in several stages. At the first stage, scientific literature on inclusive mathematics education, digital educational resources, and the digital competence of pre-service mathematics teachers was reviewed. Based on this analysis, the content and structure of the research instruments were determined.

At the second stage, the participants completed the author-developed questionnaire. This stage was designed to identify their experience in using digital resources, perceptions of the potential of these resources for inclusive mathematics teaching, and self-reported level of readiness to integrate digital tools into their future professional practice. At the third stage, the participants completed practical mathematical tasks using *GeoGebra* and *Desmos*. In addition to visualizing mathematical objects in digital environments, they were required to adapt the proposed tasks in accordance with the principles and requirements of inclusive education.

At the fourth stage, the data obtained from the questionnaire and practical tasks were systematized and subjected to quantitative analysis. Participants' self-reported readiness scores were compared with their performance on the practical tasks. Descriptive statistical methods were used to analyze the research data. For categorical variables, absolute frequencies ( $f$ ) and percentage distributions ( $P$ ) were calculated using the following formula:

$$P = \left( \frac{f}{N} \right) \times 100\%$$

where  $f$  represents the number of participants who selected a particular response and  $N$  represents the total number of participants. For the Likert-scale items and scores obtained from the practical tasks, the arithmetic mean was calculated as follows:

$$\bar{x} = \frac{\sum_{i=1}^N x_i}{N}$$

where  $x_i$  represents the individual score of each participant and  $N$  represents the total number of participants.

These descriptive measures were used to characterize pre-service mathematics teachers' readiness to use digital educational resources in inclusive teaching, their perceptions of the didactic potential of digital tools, and their performance on the practical mathematical tasks.

Correlation analysis was employed to examine the relationship between participants' self-reported readiness and their practical performance. Participants' self-assessment scores regarding their readiness to use digital educational resources in inclusive mathematics teaching were compared with their total scores on the GeoGebra- and Desmos-based practical tasks. The relationship between these two variables was assessed using Pearson's correlation coefficient ( $r$ ):

$$r = \frac{\sum_{i=1}^N (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^N (x_i - \bar{x})^2} \sqrt{\sum_{i=1}^N (y_i - \bar{y})^2}}$$

where  $x_i$  represents a participant's self-reported readiness to use digital resources in inclusive mathematics teaching,  $y_i$  represents the participant's total score on the practical tasks,  $\bar{x}$  and  $\bar{y}$  represent the corresponding mean values, and  $N$  represents the total number of participants.

A positive correlation coefficient indicated that higher levels of self-reported readiness tended to be associated with higher practical performance scores, whereas a negative coefficient indicated an inverse relationship between the two variables. Statistical significance was evaluated at the  $p < 0.05$  level.

In addition, performance on the practical tasks was analyzed separately according to five criteria: mathematical accuracy, use of digital tools, visualization, inclusive adaptation, and task differentiation. Mean scores were calculated for each criterion, and the results obtained from the GeoGebra- and Desmos-based tasks were compared. This analysis provided a more differentiated assessment of participants' ability not only to work accurately with mathematical content but also to visualize it in a digital environment and adapt it to the requirements of inclusive education.

The quantitative findings were presented in tables and graphical form. The figures illustrated the percentage distributions obtained from the questionnaire, mean scores for the practical tasks, and the distribution of pre-service mathematics teachers across different levels of readiness. This approach enabled the participants' self-reported readiness identified through the questionnaire to be considered alongside their performance-based readiness demonstrated through the practical mathematical tasks.

### Results of the study

The findings provided a multidimensional perspective on pre-service mathematics teachers' readiness to use digital educational resources in inclusive education. The analysis focused on several interrelated indicators, including participants' experience with digital resources, their performance on practical tasks completed in *GeoGebra* and *Desmos*, their levels of practical readiness, and the relationship between self-reported readiness and actual task performance. First, participants' experience with different digital educational resources used in mathematics teaching was analyzed. Since respondents were allowed to select more than one response option, the cumulative percentage

across the categories could exceed 100%. Participants' reported use of digital educational resources in mathematics teaching is presented in Table 2.

Table 2. Pre-Service Mathematics Teachers' Use of Digital Educational Resources

| Digital Educational Resource | <i>n</i> | %    |
|------------------------------|----------|------|
| GeoGebra                     | 62       | 77.5 |
| Desmos                       | 48       | 60.0 |
| LearningApps                 | 44       | 55.0 |
| Quizizz                      | 39       | 48.8 |
| Kahoot!                      | 35       | 43.8 |
| E-textbooks                  | 53       | 66.3 |
| Video materials              | 57       | 71.3 |

According to the results presented in Table 2, GeoGebra was the most widely used mathematics-specific digital resource among the participants, with 62 respondents (77.5%) reporting its use. Video materials were used by 71.3% of the participants, while 66.3% reported using e-textbooks. Desmos was used by 60.0% of the respondents. Learning Apps was reported by 55.0% of the participants, whereas Quizizz and Kahoot! were used by 48.8% and 43.8%, respectively. These findings indicate that the participants were familiar not only with general digital educational resources but also with specialized platforms designed to support the visualization of mathematical content. The distribution of these indicators is presented graphically in Figure 1.

Pre-Service Mathematics Teachers Using Digital Educational Resources (%)

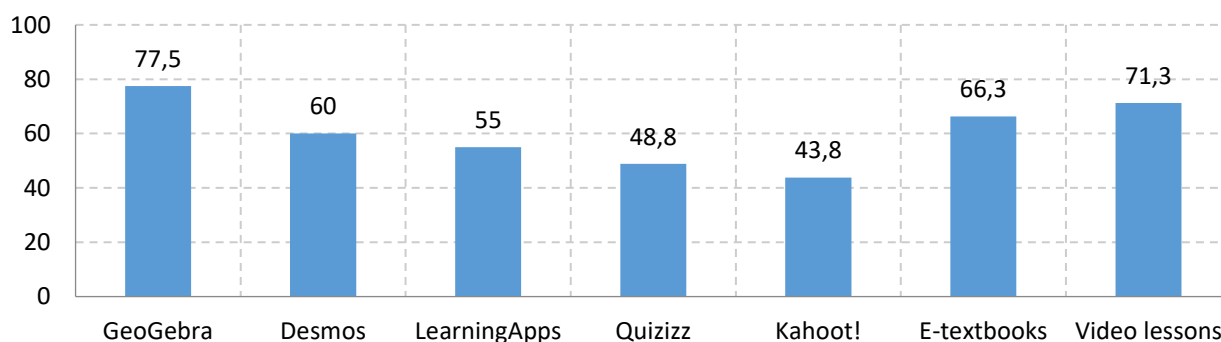


Figure 1. Percentage of Pre-Service Mathematics Teachers Using Digital Educational Resources

Figure 1 provides a comparative representation of the frequency with which different digital tools were used by the participants. The higher use of GeoGebra compared with the other platforms indicates that digital environments designed to visualize mathematical objects and functions occupy an important place in the participants' experience with technology-enhanced mathematics learning. During the practical stage of the study, participants' ability to use digital mathematics environments to complete specific mathematical tasks was assessed. The tasks performed in GeoGebra and Desmos were evaluated according to five criteria: mathematical accuracy, use of digital tools, visualization, inclusive adaptation, and task differentiation. The maximum score for each criterion was 2 points.

The mean scores for the GeoGebra and Desmos tasks across the five assessment criteria are presented in Table 3.

According to the data presented in Table 3, mathematical accuracy showed the highest mean score in both digital environments. The mean score for this criterion was  $M=1.72$  for the GeoGebra task and  $M=1.66$  for the Desmos task. Visualization also demonstrated relatively high scores, with mean values of  $M=1.68$  and  $M=1.63$ , respectively. For the use of digital tools, the mean score was  $M=1.61$  in GeoGebra and  $M=1.58$  in Desmos.

Table 3. Mean Performance Scores for Practical Tasks Completed in GeoGebra and Desmos

| Assessment Criterion  | GeoGebra, M | Desmos, M |
|-----------------------|-------------|-----------|
| Mathematical accuracy | 1.72        | 1.66      |
| Use of digital tools  | 1.61        | 1.58      |
| Visualization         | 1.68        | 1.63      |
| Inclusive adaptation  | 1.42        | 1.38      |
| Task differentiation  | 1.35        | 1.31      |

In contrast, inclusive adaptation and task differentiation yielded lower mean scores than the other assessment criteria. The mean score for inclusive adaptation was  $M=1.42$  for the GeoGebra task and  $M=1.38$  for the Desmos task. Similarly, the mean scores for task differentiation were  $M=1.35$  and  $M=1.31$ , respectively. In contrast, inclusive adaptation and task differentiation yielded lower mean scores than the other assessment criteria. The mean score for inclusive adaptation was  $M = 1.42$  for the GeoGebra task and  $M = 1.38$  for the Desmos task. Similarly, the mean scores for task differentiation were  $M = 1.35$  and  $M = 1.31$ , respectively. A comparison of the mean scores across the five assessment criteria for the GeoGebra and Desmos tasks is presented in Figure 2.

Mean Assessment Scores for Practical Tasks in GeoGebra and Desmos

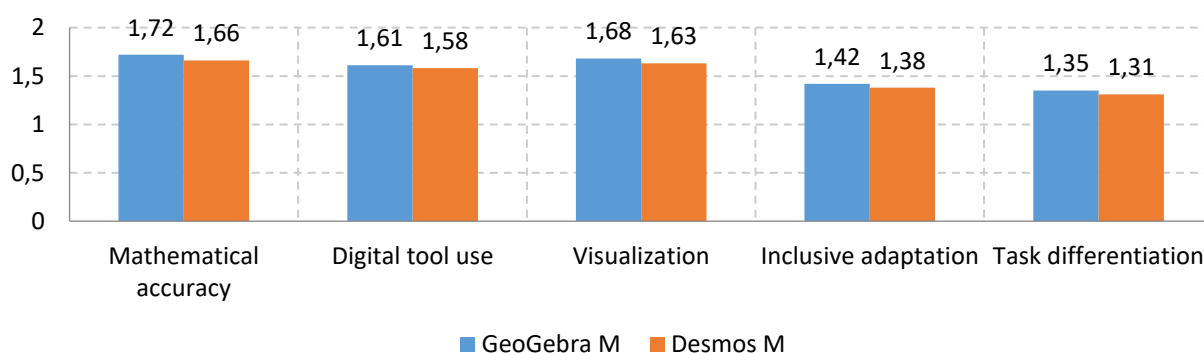


Figure 2. Mean Scores for the Assessment Criteria of Practical Tasks Completed in GeoGebra and Desmos

The results shown in Figure 2 indicate that mathematical accuracy and visualization received relatively higher mean scores in both digital environments, whereas inclusive adaptation and task differentiation received lower scores. Based on the total scores obtained from the practical tasks, participants' readiness to use digital resources in inclusive mathematics teaching was classified into three levels: low (0–3 points), moderate (4–7 points), and high (8–10 points). The distribution of participants across these readiness levels is presented in Table 4.

Table 4. Practical Readiness Levels of Pre-Service Mathematics Teachers

| Readiness Level | Score Range | n            | %            |
|-----------------|-------------|--------------|--------------|
| Low             | 0–3         | Excel result | Excel result |
| Moderate        | 4–7         | Excel result | Excel result |
| High            | 8–10        | Excel result | Excel result |
| Total           |             | 80           | 100.0        |

The distribution of participants across the three readiness levels provides an overall indication of their practical competence in using digital resources for inclusive mathematics teaching. The results reflect differences in participants' ability to combine mathematical knowledge with the effective use

of digital tools, visualization, inclusive adaptation, and task differentiation. A graphical representation of the distribution across the three readiness levels is provided in Figure 3.

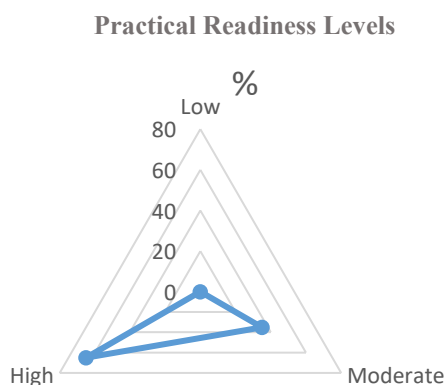


Figure 3. Practical Readiness Levels of Pre-Service Mathematics Teachers for Using Digital Resources in Inclusive Mathematics Teaching

At the next stage of the study, the relationship between participants' self-reported readiness to use digital resources in inclusive mathematics teaching and their total scores on the practical tasks was examined. Participants rated their perceived readiness on a 0–10-point scale, while practical readiness was determined based on their performance on the GeoGebra- and Desmos-based tasks.

Overall, the quantitative findings revealed variation in pre-service mathematics teachers' experience with digital educational resources. Among the resources examined, GeoGebra, video materials, and e-textbooks showed relatively high levels of use. In the assessment of practical tasks, comparatively higher scores were observed for mathematical accuracy and visualization, whereas inclusive adaptation and task differentiation received lower scores. The relationship between participants' self-reported readiness and their practical performance was further examined through correlation analysis.

A comparison of the mean scores across the five assessment criteria for the GeoGebra and Desmos tasks is presented in Figure 4.

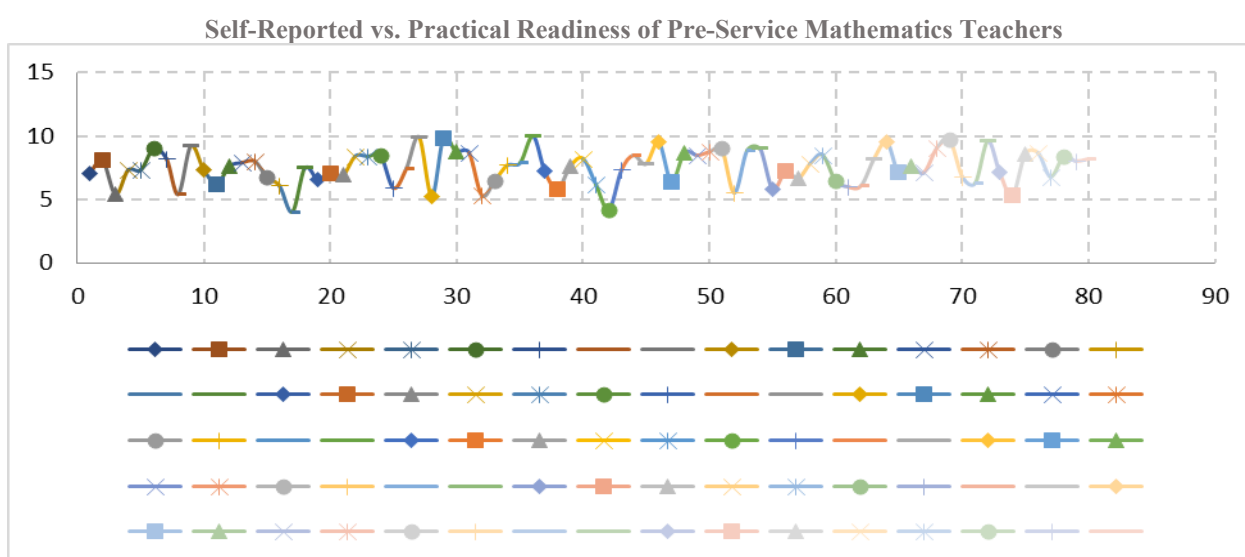


Figure 4. Relationship Between Self-Reported and Practical Readiness of Pre-Service Mathematics Teachers

Each point in the figure represents two indicators for an individual participant. The horizontal axis shows the participant's self-reported readiness to use digital resources in inclusive mathematics teaching, while the vertical axis represents the total score obtained from the practical tasks. The specific correlation coefficient was determined using an appropriate statistical test after examining the distributional characteristics of the data. Overall, the quantitative findings revealed variation in pre-service mathematics teachers' experience with digital educational resources. Among the resources examined, GeoGebra, video materials, and e-textbooks showed relatively high levels of use. In the assessment of practical tasks, comparatively higher scores were observed for mathematical accuracy and visualization, whereas inclusive adaptation and task differentiation received lower scores. The relationship between participants' self-reported readiness and their practical performance was further examined through correlation analysis.

## **Discussion**

The findings indicate that although pre-service mathematics teachers had developed a relatively broad experience of using digital educational resources, their readiness to adapt these resources to the requirements of inclusive teaching was not equally developed. Participants' familiarity with resources such as GeoGebra, Desmos, e-textbooks, and video materials suggests that digital tools are becoming increasingly integrated into their professional preparation. However, a noticeable difference emerged between the technical use of digital tools and their pedagogically appropriate adaptation to learners with diverse educational needs. This distinction highlights the need to conceptualize digital competence not merely as technological proficiency, but as the ability to integrate mathematical content, pedagogical strategies, and individual learner needs.

GeoGebra was identified as one of the most frequently used mathematics-specific digital resources among the participants. The practical tasks also produced comparatively high scores for mathematical accuracy and visualization. This finding may be associated with GeoGebra's capacity to represent abstract mathematical objects dynamically, demonstrate changes in parameters, and facilitate the visual exploration of mathematical relationships. Previous research on pre-service mathematics teachers' acceptance of GeoGebra has similarly demonstrated that perceived usefulness and ease of use are associated with intentions to employ the platform in future professional practice [10].

This finding is also consistent with studies examining the relationship between technological, pedagogical, and content knowledge. Yildiz and Arpaci demonstrated that pre-service mathematics teachers' intentions to continue using GeoGebra are influenced by their technological pedagogical content knowledge (TPACK), performance expectancy, and social factors [11]. From this perspective, the ability to use a digital tool should not be considered separately from mathematical content. In addition to mastering the technical functions of a digital platform, future teachers need to understand the specific didactic purpose that the technology serves when explaining a particular mathematical concept.

The relatively high visualization scores obtained in the GeoGebra- and Desmos-based practical tasks are particularly noteworthy. Representing mathematical functions and their graphs in dynamic environments enables learners to observe relationships between parameters visually. Research conducted in the context of universities in Kazakhstan has also highlighted the potential of GeoGebra for accurately constructing mathematical objects, dynamically modifying them, and visually exploring mathematical properties [12]. Digital visualization in inclusive mathematics education can therefore be viewed not simply as a means of illustration but as a pedagogical strategy for improving access to abstract mathematical content.

At the same time, inclusive adaptation and task differentiation received lower scores than mathematical accuracy and visualization. This represents one of the key findings of the present study. Although a future teacher may be able to construct a mathematically correct graph in a digital environment, adapting the same material for a learner with special educational needs, differentiating it across several levels of complexity, or selecting appropriate forms of additional support may present greater challenges. Meaney et al., in examining the potential of digital tools to support diverse

learners, similarly identified considerable variation in how pre-service and practicing teachers evaluated the suitability of different digital tools for particular groups of learners [13].

These findings emphasize the importance of purposeful professional preparation for inclusive mathematics education. Scherer and Bertram found that pre-service teachers' beliefs and self-efficacy concerning inclusive mathematics teaching can change over the course of teacher education programs [14]. Thus, competence in inclusive mathematics teaching should not be regarded as a general professional skill that develops automatically. Instead, it should be systematically fostered through targeted learning experiences and practice-oriented tasks during university-based teacher education.

In this respect, the design of the practical tasks used in the present study is particularly relevant. Participants were required not merely to use ready-made digital materials but to construct mathematical tasks in digital environments, visualize mathematical relationships, and redesign the tasks in accordance with inclusive education requirements. Previous studies in which pre-service mathematics teachers designed mathematical modelling activities by integrating different digital tools have also emphasized the importance of connecting technology use with the design of subject-specific learning tasks in professional teacher preparation [15].

The findings therefore suggest that digital and inclusive competencies should not be developed as separate components of mathematics teacher education but rather within an integrated subject-specific and methodological framework. For example, instead of limiting instruction to the technical functions of GeoGebra or Desmos, teacher education programs could require students to develop standard, visualized, step-by-step, and differentiated versions of the same mathematical task. Research on the integration of interactive mathematical resources into teacher education similarly emphasizes the importance of preparing teachers not only as users of digital resources but also as designers capable of evaluating, adapting, and transforming these resources into meaningful learning materials [16].

The practical significance of the study lies in its implications for incorporating learning activities that connect digital mathematics environments with inclusive pedagogy into pre-service mathematics teacher education. Such activities may include visualizing mathematical content, managing the cognitive demands of tasks, developing step-by-step instructions, providing additional visual support, and designing tasks at different levels of complexity while maintaining mathematical accuracy. Studies involving targeted GeoGebra training for pre-service mathematics teachers have reported improvements in technological and pedagogical knowledge, further supporting the potential value of structured practical preparation at the university level [17].

Future studies could extend the sample to include pre-service mathematics teachers from several teacher education institutions and compare participants across different years of study. An experimental design comparing participants' performance before and after a targeted training program on the inclusive use of digital mathematics resources could provide stronger evidence of changes in professional competence. Future research could also develop and evaluate inclusive digital tasks across different areas of mathematics, including geometry, algebra, probability, and statistics.

## **Conclusion**

The study demonstrates that the use of digital educational resources in inclusive mathematics teaching requires the professional preparation of pre-service mathematics teachers to integrate subject-specific, digital, and inclusive competencies. The research examined participants' experience with digital resources, the potential of these tools for visualizing mathematical content, and their ability to adapt practical tasks to inclusive education requirements. Performance on the GeoGebra- and Desmos-based practical tasks showed comparatively strong results in mathematical accuracy and visualization. These findings indicate that participants were able to use digital mathematics environments to construct function graphs, represent relationships between mathematical objects, and make abstract concepts more visually accessible.

At the same time, the comparatively lower scores for inclusive adaptation and task differentiation demonstrate that technical proficiency with digital tools alone is insufficient for their effective use in inclusive education. Future mathematics teachers need not only to understand the functional capabilities of digital resources but also to develop the ability to modify mathematical tasks according to learners' individual educational needs, structure activities into manageable stages, provide additional visual support, and differentiate levels of complexity.

The findings support the systematic integration of digital and inclusive competencies within pre-service mathematics teacher education. Practice-oriented activities based on GeoGebra, Desmos, and other digital mathematics environments could therefore be incorporated into teacher education programs to provide future teachers with opportunities to design, evaluate, and adapt mathematical tasks for diverse learners.

Overall, the initial research hypothesis was supported: digital educational resources provide important opportunities for mathematical visualization and task differentiation; however, their effective application in inclusive education depends on the future teacher's ability to adapt digital tools pedagogically to the specific educational needs of learners.

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