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Investigation of candidate mathematics teachers' critical thinking dispositions

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Abstract

This paper investigated the impact of a technology-enhanced instructional model developed to foster student's critical reasoning abilities on candidate mathematics teachers' critical thinking dispositions. To facilitate technology-supported instruction in transformation geometry and to enhance the critical thinking skills of pre-service teachers, lesson plans were developed in alignment with the content-based teaching approach, which is recognized as an effective method for promoting critical thinking. These lesson plans were subsequently implemented over the course of 14 instructional hours. The objectıves of the lesson plans were formed by the objectıves of transformatıonal geometry of secondary school mathematıcs course. The applıcatıons ın the teachıng of these objectıves were desıgned to develop the crıtıcal thınkıng skılls ıdentıfıed by facione (1990). The study was conducted during the fall term of the 2019-2020 academic year, with 56 candidate teachers in the fourth grade at a state university in the Marmara Region in Turkey. The research used the Critical Thinking Disposition (CTD) scale as a data collection tool. The researchers implemented the CTD scale on candidate teachers as a pre- and post-test. Then, the researchers evaluated the results using the t-test for dependent samples and assessed the different aspects of the CTD (higher cognition, flexibility, systematicity, perseverance and patience, open-mindedness) framework. As a result of the research, according to the data of the CTD scale, implemented as a pre- and post-test on the candidate teachers, the pre-test critical reasoning abilities and sub-dimension mean points of the candidate teachers increased after the designed instructional model applications. Considering evaluations of these score increases statistically, there was a 0.05 significance level. The instructional model applications contributed to candidate teachers' critical thinking dispositions and sub-dimensions.

Keywords: Critical Thinking, Critical Thinking Disposition Scale, GeoGebra, Candidate Mathematics Teachers.

İlköğretim matematik öğretmeni adaylarının eleştirel düşünme eğilimlerinin incelenmesi

Öz

Bu araştırmada, eleştirel düşünme becerilerinin gelişimine katkı sağlayabilmek için tasarlanan teknoloji destekli öğretim modeli uygulamalarının ilköğretim matematik öğretmeni adaylarının eleştirel düşünme eğilimlerine katkısı incelenmiştir. Teknoloji destekli dönüşüm geometrisi öğretiminde kullanılmak üzere, öğretmen adaylarının eleştirel düşünme becerilerini artırabilmeyi hedefleyen, eleştirel düşünme öğretimine yönelik yaklaşımlardan içerik temelli öğretim yaklaşımına uygun olarak ders planlarının hazırlanmıştır. Hazırlanan ders planları 14 ders saati uygulanmıştır. Ders planlarının amaçları, ortaöğretim matematik dersinin dönüşümsel geometri amaçları doğrultusunda oluşturulmuştur. Bu amaçların öğretimindeki uygulamalar, Facione (1990) tarafından tanımlanan eleştirel düşünme becerilerinin geliştirilmesine yönelik olarak tasarlanmıştır. Araştırma, 2019-2020 eğitim-öğretim yılı güz döneminde, Marmara Bölgesindeki bir devlet üniversitesinin Eğitim Fakültesi İlköğretim Matematik Öğretmenliği 4. Sınıftaki 56 öğrencileriyle gerçekleştirilmiştir. Araştırmada veri toplama aracı olarak Eleştirel

Düşünme Eğilimi (EDE) ölçeği kullanılmıştır. EDE ölçeği öğretmen adaylarına ön test ve son test olarak uygulanmıştır. Elde edilen verilere bağımlı örneklemler için t testi uygulanmıştır ve veriler EDE ölçeği alt boyutları kapsamında değerlendirilmiştir. Araştırmanın sonucunda, öğretmen adaylarına ön test ve son test olarak uygulanan EDE ölçeği verilerine göre, tasarlanan öğretim modeli uygulamaları sonunda öğretmen adaylarının ön test eleştirel düşünme eğilimleri ve alt boyutları puan ortalamalarında artış meydana gelmiştir. Bu puan artışları istatistiksel anlamda değerlendirildiğinde 0,05 anlamlılık düzeyinde manidar bulunmuştur. Ön test ile son test verileri arasında anlamlı bir fark olduğu, yani tasarlanan dönüşüm geometrisi dersinin öğrencilerin eleştirel düşünme eğilimlerinin gelişimine istatistiksel anlamda katkı sağladığı sonucuna ulaşılmıştır. Öğretim modeli uygulamaları öğretmen adaylarının eleştirel düşünme eğilimlerine ve alt boyutlarına katkı sağlamıştır.

Anahtar Kelimeler: Eleştirel Düşünme, Eleştirel Düşünme Eğilimi Ölçeği, GeoGebra, Matematik Öğretmen Adayları

Introduction

In the contemporary age, swift access to information has become readily attainable through advancements in information and communication technologies. However, alongside accurate information, a plethora of misinformation is available. Therefore, school curricula need to enable learners to acquire the capacity to locate accurate and practical information and to improve their ability to make high-level judgments. For this reason, contemporary educational programs should include practices that will inspire students to use high-level intellectual abilities such as creativity, critical reasoning, problem-solving, decision-making, entrepreneurship, and cooperation (Korkmaz, 2018).

The incorporation of practices aimed at fostering critical thinking is a salient feature of contemporary educational curricula, including those implemented within our country. Prominent organizations such as the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the European Education Council have emphasized increasing learners' participation in the educational system. They have pointed to the importance of fostering individual flourishing, being creative, being self-reliant, improving intellectual capacity and especially cultivating skills of critical reasoning (Maričića, 2015). Similarly, Turkish educational programs strongly focus on the continuing need to instil advanced thinking skills in students (MoNE, 2018, p. 4). Paul and Elder (2013) have defined critical thinking as a mode of thinking in which individuals skillfully analyze, assess, and restructure their thoughts about any subject, content, or problem. Kurnaz (2013, p. 12) has expressed critical thinking as investigating the truth about something entirely, with all its benefits and drawbacks, both apparent and hidden, to conclude. According to Halpern (2014), critical thinking involves using cognitive skills or strategies that enhance the likelihood of a desired outcome. Eğmir (2016) has described thinking with a critical eye as a methodical procedure of scepticism using criticizing queries to improve thinking, formulating more powerful thoughts and making more appropriate judgments. As in the various approaches to defining thinking with a critical eye, including such an important skill in school curricula is essential. It is essential to cultivate a critical community of individuals who can reason with a critical mind (Eğmir, 2018). Critical thinking is an interdisciplinary thinking process that involves the individual's thought processes and the ability to evaluate and analyze information (Yeşilyurt, 2021). Critical thinking skills help individuals analyze media messages, advertisements and propaganda elements better and distinguish between accurate and reliable information (Söylemez, 2016; Kurnaz & Nas, 2022). Critical thinking enables the production of knowledge by establishing a connection with newly acquired knowledge on top of previous knowledge. For this purpose, it enables effective and active use of processes such as investigating the accuracy of the source of information, providing a different perspective on problems, evaluating the results and making decisions (Yıldız-Çolak, 2025).

The purposes of mathematics curricula at elementary and middle schools highlight the need to develop individuals with critical thinking skills (MoNE, 2018). To accomplish this objective, placing the concept of thinking in a critical perspective in mathematics teaching will greatly help foster the growth of such abilities in learners. These abilities will also improve, incorporating activities, exercises and assignments to enhance students' capacity to reason critically about the course materials.

A critical mindset is a neural function which can be successfully achieved through active teaching techniques (Kökdemir, 2012). In that respect, teachers have a crucial duty. The effectiveness of teaching approaches intended to encourage the acquisition of the ability to reason critically will depend on the teachers who implement them in their classrooms. Norris (1985) asserts that teachers should enable students to gain critical thinking skills (cited in Sezer, 2008). Meanwhile, Ennis (1991) suggests that the key player is the "teacher" when teaching students to use critical reasoning abilities. Demirci (2000) emphasizes that the ability of learners to acquire a critical mindset is linked to whether teachers or students have the necessary qualifications. In this context, the Teacher Training Strategy (2017-2023) published by the Ministry of National Education emphasizes the close relationship between the functionality of education systems and the qualifications of teachers, highlighting the key role that teachers play (MoNE, 2017).

Since candidate teachers represent the future teachers and are in the formative stages of their training, they must graduate with well-established critical thinking skills. Whereas certain reports across the scientific research base highlight the fact that teachers possess high levels of critical thinking (Duğan & Aydın, 2018; Hofreiter, Monroe & Stein, 2007; Karademir, 2013; Karalı, 2012; Kong, 2001; Yeşilpınar, 2011), some research findings also indicate that teachers tend to have low or moderate levels of critical thinking disposition and rarely incorporate activities that promote critical thinking skills in their classrooms (Gelen, 2002; Korkmaz, 2009; Özsevgeç & Altun, 2015; Palavan, Gemalmaz & Kurtoğlu, 2015; Şengül & Üstündağ, 2009). Recent research, in particular, highlights this disposition towards lower and moderate levels of critical thinking disposition (Altıntaş, 2019; Aşık & Saka, 2019; Durnacı & Ültay, 2020).

The rapidly evolving information and communication technologies necessitate changes in traditional educational environments. In line with technological advancements, primary and secondary mathematics education programs intend to utilize information and communication technologies in mathematics education. Expressions such as "Utilization of information and communication technologies," "Interactive work with appropriate information and communication technologies," and "Utilization of three-dimensional dynamic geometry software" emphasize this point. Thus, students should become acquainted with the innovations of the era in mathematics education, such as dynamic geometry software, and gain the ability to use these innovations (MoNE, 2018) effectively.

Dynamic Geometry Software (DGS) allows students to make inductive and deductive reasoning, reach generalizations, and acquire knowledge. Through DGS, students can comfortably enter a research environment, explore, make assumptions, test them, reject or formalize them, and provide explanations. Moreover, DGS enables students to develop higher-order cognitive skills and make inferences through the relationships they establish while thinking about geometric objects (Baki, 2001; Baydaş, 2010; Borazan, 2019; Güven & Karataş, 2003; Sanders, 1998).

Considering the significance of critical thinking, the role of teachers in teaching a critical attitude, the connection of mathematical literacy and thinking with critical awareness, and the contribution of Dynamic Geometry Software (DGS) environments to critical thinking together, a technology-assisted classroom design should be available to facilitate the acquisition of the candidate elementary mathematics teachers' critical reasoning skills and tendencies.

Within this context, this research implemented the critical thinking disposition scale on candidate teachers at the beginning (pre-test) and end (post-test) of the technology-enhanced instructional model intended to promote the acquisition of critical thinking abilities. Based on the collected data, the following research problem was investigated:

According to the pre- and post-test results of the candidate teachers, pre-service teacher candidates are evaluated based on the following metrics:

1. What is the score obtained on the pretest?
2. What is the score obtained on the posttest?
3. Based on the comparative analysis of pre-test and post-test data, does the implementation of the designed teaching model demonstrate a statistically significant impact on the critical thinking tendencies of pre-service teachers?

Method

Research Design

This research employed a quantitative research approach using a single-group pre-test-post-test experimental design. The researchers tested hypotheses for the meaningfulness of the comparison between a particular group's pre- and post-test scores. This design tested the effect of the experimental process through a study on a single group. The study obtained measurements of the dependent variable of the subjects before the pre-test and after the post-test, using the same subjects and measuring instruments (Büyüköztürk et al., 2010, p. 198).

The one-group pre- and post-test procedure is one of the more limited test procedures. Nevertheless, Creswell (2012) has noted that choosing a one-group test procedure in a study creating and adopting a novel teaching methodology is intrinsic to the essence of the research. The study implemented the Critical Thinking Disposition (CTD) scale on the study group to gather statistical results as a pilot study before the applications and as a follow-up test after introducing the planned instructional model.

Participants

The researchers conducted the study in the first term of the 2019-2020 education year, with 56 candidate teachers in their final year of the elementary mathematics teaching program at a public university in the Marmara region. Of the candidate teachers, 90% (50) were female, and 10% (6) were male. The researchers conducted implementations within the scope of the Elementary Mathematics Teaching course.

The study used a purposeful criterion sampling method to select the participants among candidate teachers. In criterion sampling, the aim is to create observation units from individuals, events, objects, or situations with specific attributes in a study (Büyüköztürk et al., 2019). The research criteria for selecting candidate teachers included not having weak academic performance, expressing their thoughts comfortably, volunteering, being proactive, and being open to sharing. The researchers selected the criterion of not having weak academic performance because a lack of mathematical knowledge might negatively affect critical thinking skills. Additionally, students with weak academic performance did not meet the criterion of volunteering. The research included the criteria of expressing their thoughts comfortably and being proactive in collecting as much data as possible. Since the main purpose was not to teach the outcomes, but to investigate the effect of geometry on critical thinking skills, students with complete readiness ın transformational geometry were selected.

Data Collection Tools

The research employed the Critical Thinking Disposition (CTD) Scale as a pilot test and follow-up test to measurably assess the transformation in candidate teachers' critical thinking dispositions brought about by the developed classroom practice framework. The Critical Thinking Disposition Scale was originally developed by Semerci (2000) and later revised by Semerci (2010; 2016).

The scale consists of a total of 49 items (statements). The rating of the scale is as follows: "Strongly Agree (5), Mostly Agree (4), Somewhat Agree (3), Mostly Disagree (2), Strongly Disagree (1)" (Semerci, 2016). The scale comprises five subscales:

- Upper cognition with 14 items (Statements 1-14).
- Flexibility with 11 items (Statements 15-25).
- Systematicity with 13 items (Statements 26-38).
- Perseverance with 8 items (Statements 39-46).
- Open-mindedness with 3 items (Statements 47-49) (Semerci, 2000; Semerci, 2016).

The consistency factor of the measurement scale is 0.94 (Bayraktar & Güder, 2019). Since this coefficient is close to 1, the scale is reliable.

In the Critical Thinking Disposition (CTD) Scale, the following score ranges are associated with different levels of critical thinking disposition within each subscale: For the Upper Cognition subscale (14-70), scores between 14-33 indicate a weak disposition, scores between 33-52 indicate a moderate disposition, and scores between 52-70 indicate a high disposition. For the Flexibility subscale (11-55), scores between 11-26 indicate a weak disposition, scores between 26-41 indicate a moderate disposition, and scores between 41-55 indicate a high disposition. For the Systematicity subscale (13-65), scores between 13-30 show a low mood, scores between 30-47 show a medium mood, and scores between 47-65 indicate a high disposition. For the Perseverance subscale (8-40), scores between 8-19 indicate a weak disposition, scores between 19-29 indicate a moderate disposition, and scores between 29-40 indicate a high disposition. For the Open-mindedness subscale (3-15), scores between 3-7 indicate a weak disposition, scores between 7-11 indicate a moderate disposition, and scores between 11-15 indicate a high disposition (Aydın & Duğan, 2018).

The present research implemented the Critical Thinking Disposition (CTD) Scale on candidate teachers as a pre- and post-test. The study used a normality test initially to determine whether the differences between the scores derived from the pre- and post-test followed a normal distribution and to assess whether the designed instructional model had a significant impact on the capacity for critical thinking of candidate teachers. Then, the researchers interpreted the results using a t-test for paired results at the 0.05 statistical threshold. A paired sample t-test is a parametric test performed to ascertain if a graphically meaningful distinction exists among the averages of the results of two consecutive measurements on the same measurement dataset. For this test to yield reliable results, the data series representing the differences between the means being compared should exhibit normal distribution characteristics (Can, 2016, p. 136). This test is quite robust, and even when the sample size exceeds 30, it can provide acceptable results even if the distribution does not exhibit normality (Green & Salking, 2005, p. 162, cited in Can, 2016). The researchers obtained permission to use the scale via email.

Data Analysis

This study employed IBM SPSS 22 for statistical evaluation of the results. The researchers measured the same data set twice and used a matched sample t-test to assess if the statistical deviation was significant. For this test to yield reliable results, the data series representing the differences between the means being compared should exhibit normal distribution characteristics (Can, 2016, p. 136).

The researchers performed a quantitative analysis by converting the data from the Critical Thinking Disposition (CTD) Scale, given to participants as a pre- and post-test in the research. Initially, the researchers concluded that the values presented a regular spread. A matched-sample t-test was employed for the values that presented a normal distribution. Considering the data obtained in the research, there was a significance level of $p=0.05$.

Presentation of the Implementation

First, the researchers implemented the Critical Thinking Disposition (CTD) Scale to candidate teachers as a pre-test. Subsequently, the researchers provided introductory lessons to enhance technological competencies, focusing on GeoGebra. These lessons spanned a total of five lesson hours over two weeks. During these sessions, the researchers introduced the features of GeoGebra that would be frequently used in the implementation and conducted activities to understand and reinforce these features. The purpose of the GeoGebra orientation sessions was to address any potential data loss, errors or shortcomings that might occur in the critical thinking data gathered from candidate teachers due to a general absence of understanding about how to use GeoGebra. Additionally, the researchers delivered a presentation (lasting one lesson hour) to candidate teachers about topics such as "What is Thinking? What is Critical Thinking?", "The Importance of Critical Thinking in Educational Systems," "The Role of the Teacher in Critical Thinking Education," and "The Role of Critical Thinking in Mathematics Instruction." The researchers finalized the preparatory steps for adopting the developed educational concept.

The preparation of lesson plans guided the implementation process of the designed instructional model. The researchers designed these lesson plans meticulously in line with a content-based instructional approach intended to strengthen the critical reasoning abilities of candidate teachers. In this approach, the principles and rules of content and critical thinking are combıned and students are encouraged to think critically during content learning. In this approach, content teaching is at the forefront and the general principles of critical thinking are not explicitly stated. Also, the researchers structured learning outcomes of the lesson plans around the transformations in geometry, a topic within the secondary school mathematics curriculum. The instructional activities embedded within these plans were purposefully designed to foster critical thinking skills, as delineated by Facione (1990). As a part of the 11th and 12th-grade mathematics curriculum, geometric transformations encompassed the targeted learning outcomes, as in Table 1.

Table 1. Secondary School Mathematics Course, Geometric Transformation Topics and Learning Outcomes

Grade	No	Topics	Learning Outcomes
11	11.3.3.	Transformations of Functions	**1.** Using transformations creates new function charts from the existing function graph. **a)** Places emphasis on the symmetry properties of even and odd functions. **b)** Delivers graphs of transformations such as $y=f(x)+b$, $y=f(x-a)$,

			$y=kf(x)$, $y=f(k\text{x})$, $y=-f(x)$, $y=f(-x)$ via the use of ICT (Information and Communication Technologies).
12	12.4.1.	Basic Transformations in the Cartesian Plane	**1.** Determines the coordinates of the image of a point under translations, rotations, and symmetry transformations in the Cartesian plane, given its coordinates. **a)** Recalls concepts of translation, symmetry, and rotation. **b)** Emphasizes symmetries of a point for another point, axes, the line $y=x$, and a line. Symmetries for a line are not covered. **c)** Translation, symmetry, and rotation are taught via the use of ICT. **2.** Resolves problems involving fundamental transformations and their compositions. **a)** Includes modelling exercises. **b)** Gives natural and human-made models.

Table 1 presents worksheets prepared for each learning outcome. Each worksheet is designed specifically for one learning outcome. Additionally, table 2 presents the learning outcomes of the worksheets that make up the lesson plans.

Table 2. Worksheets and Targeted Learning Outcomes

Lesson Plan	Learning Outcomes No.	Learning Outcomes
First Worksheet	11.3.3.1.a	Emphasizes the symmetry properties of even and odd functions' graphs.
Second Worksheet	11.3.3.1.b	Delivers the graphs of transformations $y=f(x)+b$, $y=f(x-a)$, $y=kf(x)$, $y=f(k\text{x})$, $y=-f(x)$, $y=f(-x)$ via the use of ICT.
Third Worksheet	12.4.1.1	Aims to reach the learning outcomes related to the "translation transformation" for the learning outcome.
Fourth Worksheet	12.4.1.1	Aims to reach the learning outcomes related to the "rotation transformation" for the learning outcome.
Fifth Worksheet	12.4.1.1	Aims to reach the learning outcomes related to the "reflection transformation" for the learning outcome.

A sample section of the first worksheet is as follows:

Worksheet One:

EVEN AND ODD FUNCTIONS

Define the concepts of even and odd functions in mathematical form. Give an example each.

Let's write it down:
Even Function:

Odd Function:

If any;
My Shortcomings

....

....

My Mistakes

....

....

Question 1: Does a function have to be an odd or even function? Why? Express your thoughts in a few sentences.

Symmetry Properties Of Graphs Of Odd And Even Functions

Applications with GeoGebra:

Example 1) Let f:R→R; let f(x)= x^3-2x.

Application 1)

1) *Open the GeoGebra program.*
2) *Type x^3-2x in the input and press Enter.*
3) *After clicking on the dot icon, click anywhere on the graph and create the A point.*
4) *After typing 'reflect' in the input section, there will be a new line where written 'object' and 'point', type A,(0,0) in this line respectively and press Enter key. Point A' will be created.*
5) *When you drag point A with the cursor, point A' will also move. Observe this movement. To better observe this movement, draw the line segment by clicking on the Line Segment icon and then on the points A and A'. Observe the movement of the line segment by dragging point A with the cursor.*

My results at the end of the application are:...

....

....

The researchers used the dynamic geometry software GeoGebra during the implementations. At the heart of the instructional system adaptations, the teaching curricula are the most critical asset and guiding element for accomplishing the study's goals. They guide candidate teachers during the introduction phase and gather information for study. Figure 1 and Figure 2 give visuals related to the instructional model implementation environment.

Figure 1. Realization of GeoGebra Activities by Candidate Teachers

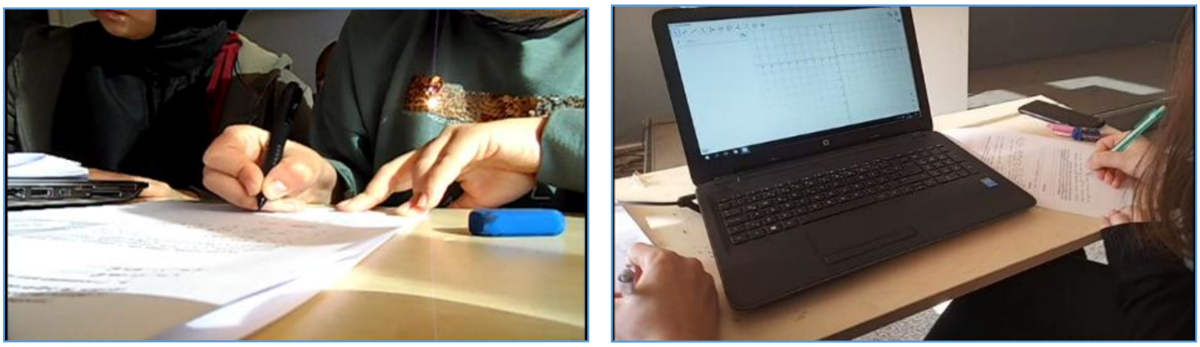

Figure 2. Completion Of Worksheets by Candidate Teachers

Details regarding the implementation processes of the study are given in the table below.

Table 3. Implementation processes of the study

Pre-practice	1. Lesson plans to be used in technology-supported transformation geometry teaching in accordance with the content-based teaching approach, which aims to increase the critical thinking skills of pre-service teachers, which is one of the approaches to critical thinking teaching. (preparation of lesson plans of the designed teaching model) 2. Application of the EDE scale.(week 1 / 1 class hour)
During practice	1. Providing an introductory course for the development of pre-service teachers' technology competencies (geogebra) (1st and 2nd weeks / 5 lesson hours.) 2. Criterion sampling method, which is one of the purposive sampling methods, was used to determine the candidate teachers (week 2) 3. Making an informative presentation on what critical thinking is (3rd week / 1 class hour) 4. Implementation of the prepared lesson plans (3rd, 4th, 5th, 6th, 7th weeks/ 14 lesson hours) 5. Obtaining data about the teaching process through the worksheets of the candidate teachers (during the implementation of the lesson plans) 6. Obtaining video recording data of the groups (during the implementation of the lesson plans) 7. Formation of lesson diaries
After practice	1. Determining the success status and critical thinking skills development of pre-service teachers for the designed teaching model applications through evaluation questions after the implementation (week 8 / 3 class hours) 2. Application of the ede scale (week 9 / 1 class hour) 3. Evaluating the process of pre-service teachers' teaching model applications with the questions in the interview form. (week 9 / 2 class hours)

Findings

In this section of the study, the following components are presented:

- Data derived from the CDT scale pretest,
- Data derived from the CDT scale post-test,
- Increase in grade point averages,
- Assessment of the normality of the CDT scale difference score series,
- Results of the dependent sample t-test conducted on pretest and posttest data, and
- A synthesis of the CDT scale data.

3.1. CDT Scale Pretest Data

This section examines the statistical significance of the designed instructional model's effect on candidate teachers' ability to use critical reasoning. The researchers implemented the CTD scale to the candidate teachers as a pre- and post-test before the instruction to quantitatively interpret the impact of the lesson plans designed to enhance the capacity of candidate teachers to develop their critical reasoning and analytical skills.

The purpose of the pre-test was to identify the current level of the candidate teachers' ability to use critical strategies and to make comparisons with the post-test. Table 4 presents the data from the CTD scale administered as a pre-test to candidate teachers.

Table 4 . Data Obtained From The CTD Scale Administered As A Pre-Test

Scale Sub-dimensions	n	Mean	Standard Deviation
Upper Cognition	49	52,78	4,959
Flexibility	49	42,29	3,571
Systematicity	49	47,90	5,030
Perseverance and Patience	49	28,59	4,203
Open-mindedness	49	11,35	1,751
Total Score	49	182,90	14,738

Table 4 indicates that candidate teachers had high levels of cognitive disposition ($\bar{X}$ = 52.78), flexibility ($\bar{X}$ = 42.29), systematicity ($\bar{X}$ = 47.90), perseverance ($\bar{X}$ = 28.59), and open-mindedness ($\bar{X}$ = 11.35) before the instruction. Based on the average score of the study group ($\bar{X}$ = 182.90), the candidate teachers showed a strong capacity for thinking in a critical sense disposition before the instruction.

At the end of the instruction, in the 9th week, the researchers implemented the CTD scale on the candidate teachers as a post-test. Table 5 presents the CTD scale data obtained from the post-test administered to candidate teachers at the end of the instruction.

Table 5. Data Obtained From The CTD Scale As A Post-Test

Scale Sub-dimensions	n	Mean	Standard Deviation
Upper Cognition	49	55,59	5,919
Flexibility	49	44,02	4,121
Systematicity	49	50,69	5,417
Perseverance and Patience	49	30,55	5,264
Open-mindedness	49	12,04	1,457
Scale Total	49	192,90	19,269

Considering the data in Table 5, the levels of upper cognition ($\bar{X}$ = 55.59), flexibility ($\bar{X}$ = 44.02), systematicity ($\bar{X}$ = 50.69), perseverance and patience ($\bar{X}$ = 30.55), and open-mindedness ($\bar{X}$ = 12.04) of the candidate teachers were at a high level at the end of the instruction. Based on the average score obtained by the study group ($\bar{X}$ = 192.90), the results indicated that future teachers had a high level of critical thinking dispositions after the instruction. Comparing the pre- and post-test results, there was an overall rise in mean scores for all sub-dimensions of the scale. Table 6 presents the increases in the average scores.

Table 6. Table of Score Average Increases

Scale Sub-dimensions	Pre-test Score Avg.	Post-test Score Avg.	Score Increase
Upper Cognition	52,78	55,59	+ 2,81
Flexibility	42,29	44,02	+ 1,73
Systematicity	47,90	50,69	+ 2,79
Perseverance and	28,59	30,55	+ 1,96

Patience			
Open-mindedness	11,35	12,04	+ 0,69
Scale Total	182,90	192,90	+ 10

Table 6 shows that the instruction provided to the candidate teachers has contributed to their critical thinking dispositions. It increased the average scores of candidate teachers' total critical thinking disposition scores and the sub-dimension scores. To determine whether these increases were statistically meaningful, the researchers performed a matched sample t-test. For this test to be applicable, the data formed by the differences between the compared values must exhibit normal distribution characteristics.

If the ratio of skewness coefficient to skewness standard error and the ratio of kurtosis coefficient to kurtosis standard error were between -1.96 and 1.96, the distribution was considered normal (Can, 2016, p.85). Table 7 presents skewness, skewness standard error, kurtosis, kurtosis standard error, the ratio of skewness coefficient to skewness standard error, and the ratio of kurtosis coefficient to kurtosis standard error for the differences in the total average scores of candidate teachers' pre-test and post-test. It also gives the differences in the average scores of the sub-dimensions of the CTD scale for the pre-test and post-test to determine the normality of the data.

Table 7. The Normality Of The CTD Scale Difference Score Dataset

Scale Sub-Dimensions Difference	Skewness	Std. Error of Skewness	Skewness/ Std. Error of Skewness	Kurtosis	Std. Error of Kurtosis	Kurtosis/ Std. Error of Kurtosis
Upper Cognition	-,193	,340	**- 0,567**	-,083	,668	**-0,124**
Flexibility	,107	,340	**0,314**	-,610	,668	**-0,913**
Systematicity	-,344	,340	**- 1,011**	,929	,668	**1,390**
Perseverance and Patience	,454	,340	**1,335**	-,298	,668	**- 0,446**
Open-mindedness	-,140	,340	**- 0,411**	-,501	,668	**- 0,75**
Scale Total (Post-Test Pre-Test)	,036	,340	**0,105**	,325	,668	**0,486**

Considering Table 7, all the difference data were within the range of -1.96 to 1.96 for the skewness-to-standard error of the skewness ratio and the kurtosis-to-standard error of the kurtosis ratio. It indicates that the data exhibited normal distribution characteristics.

Regarding the data characteristics of a regular spread, the researchers performed a matched t-test to ascertain whether the increase shown in Table 8 between the average of the pre- and post-test results was statistically meaningful. Table 8 presents the output of the matched sample t-test for the collected information.

Table 8. Results of the Matched Sample t-Test for Pre-Test and Post-Test

		n	$\bar{X}$	SS	t	p*
Pair 1	Pre-Test & Post-Test	49	-10,000	25,641	-2,730	**009**
Pair 2	Upper Cognition Pre- and Post-Test	49	-2,816	8,298	-2,376	**022**
Pair 3	Flexibility Pre- and Post-Test	49	-1,734	5,604	-2,167	**035**
Pair 4	Systematicity Pre- and Post-Test	49	-2,795	7,615	-2,570	**013**
Pair 5	Perseverance Pre- and Post-Test	49	-1,959	6,834	-2,007	**050**
Pair 6	OpenMindedness Pre- and Post-Test	49	-,693	2,247	-2,161	**036**

*p < 0,05

According to Table 8, within the scope of the CTD scale data, the impact of the educational approach to develop critical reasoning capacities of candidate teachers was statistically significant at the p=0.05 significance level. The instruction provided to candidate teachers contributed to their critical reasoning capacities. Similarly, within the scope of the CTD scale data and according to Table 8, the effect of the designed instructional model on the sub-dimensions of candidate teachers' critical thinking dispositions was statistically significant at the p=0.05 significance level. Additionally, the instruction provided to candidate teachers contributed to all sub-dimensions of their critical thinking dispositions.

Synthesis of CTD Scale Data. Table 9 presents the synthesis of the data obtained from the CTD scale.

Table 9. Synthesis of CTD Scale Data

Scale Sub-dimensions	n	Mean (pre-test)	Mean (post-test)	Score Increase	p
Upper Cognition	49	52,78	55,59	+ 2,81	**,022**
Flexibility	49	42,29	44,02	+ 1,73	**,035**
Systematicity	49	47,90	50,69	+ 2,79	**,013**
Perseverance and Patience	49	28,59	30,55	+ 1,96	**,050**
Open-mindedness	49	11,35	12,04	+ 0,69	**,036**
Scale Total	49	182,90	192,90	+ 10	**,009**

According to the results obtained in this study, significant increases were observed between pre-test and post-test scores in all sub-dimensions, and Cohen's d values are very useful in interpreting the magnitude of this change. Small to small-medium effect sizes were found for metacognition (d = 0.40), flexibility (d = 0.25), systematicity (d = 0.39), persistence and patience (d = 0.28) and open-mindedness (d = 0.10). These findings suggest that the intervention provided measurable but limited improvement in the related cognitive dispositions. On the other hand, the Cohen’s d value calculated for the total scale score was 0.50, which is considered a moderate effect size. Thıs result shows that overall, the intervention provided a significant and noteworthy improvement at the whole scale level.

According to the CTD scale data from the pre- and post-test implemented on the candidate teachers, there was an increase in average ratings of both the pre-test critical thinking dispositions and its sub-dimensions after implementing the designed instructional model. These rating improvements were academically meaningful at a significance level of 0.05. The applications of the instructional model contributed to the candidate teachers' critical thinking dispositions and sub-dimensions.

Conclusion and Discussion

Upon evaluating the total scores and sub-dimensions of the CTD scale derived from the pre-test and post-test performed on candidate teachers, it was suggested that the students exhibited a high propensity for critical thinking before and after the instructional intervention.

This conclusion diverged from prior research and contradicted the findings of Türnüklü and Yeşildere (2005), who identified critical thinking dispositions among candidate mathematics teachers as being positively disposed but falling short of a high level. It also contradicted Güneş's (2012) assertion that the capacity of candidate secondary school math teachers to engage in critical reasoning was at a moderate level. Furthermore, this result departed from the conclusion of Yüksel, Uzun, and Dost (2013), who have ascertained that the ability of future math teachers to use critical reasoning in the classroom registered at a low level. Considering the concept of critical thinking as the capacity of an individual to scrutinize, assess, and restructure their thinking processes (Paul & Elder, 2013), it was plausible to attribute the observed results to the students' disposition for critical thinking as in the comprehensive observations such as inclusive of active classroom participation, meticulous resolution of worksheet problems, and the diligent completion of GeoGebra applications, among other indicators.

Subsequently, upon the data analysis, it was evident that there existed an upswing in the mean scores on the total scale and all sub-dimensions of the CTD scale. To investigate the significance of this increase, initially, it was assumed that the results adhered to a regular spread. Following this statistical validation, the researchers examined the figures provided by the pre- and post-tests through the lens of a paired-sample t-test. The findings concluded evidence of a considerable discrepancy observed between pre- and post-testing, thus meaning that the meticulously devised instruction on transformation geometry had a statistically noteworthy contribution to the increase in students' critical thinking disposition.

This conclusion aligned with the results of Budiman (2013), who used dynamic geometry software in teaching to improve students' thinking and emphasized the importance of technology applications. It also supported the results of Maričić, Špijunović, and Lazić (2015), who investigated whether critical thinking can be developed through the design of contents (tasks) that required critical thinking and quantitatively evaluated their study with the tests. It was also in line with the results of Doğan-Dolapçıoğlu (2015), who investigated how authentic learning standards-based practices could improve critical thinking skills in fifth-grade mathematics students using quantitative results, and Hidayati and Kurniati (2018), who examined whether there was a correlation among self-paced learning and mathematical critical reasoning attitudes using scales in GeoGebra-supported 3D shape teaching activities. Additionally, the research findings aligned with those of Munandar, Usman, and Saminan (2020), who analyzed the impact of mathematics learning supported by GeoGebra software on students' critical thinking skills.

GeoGebra is a user-friendly software program that is readily accessible to its users. Research indicates that GeoGebra serves as an effective pedagogical tool for the instruction of mathematics. It is imperative that pre-service mathematics teachers develop proficiency in utilizing GeoGebra during their training at the university level. Educational sessions should be conducted to explore and discuss the integration of GeoGebra into the specified learning outcomes within primary and secondary school curricula. It follows that a pre-service teacher who receives such training is likely to become an active user of GeoGebra in their future classrooms. This engagement not only facilitates their students' success in achieving mathematics-related learning outcomes but also contributes positively to the enhancement of students' critical thinking skills.

The same study can be conducted with such as the inclusion of control groups, methodological triangulation, or longitudinal studies.

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