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RESEARCH ARTICLE

Pre-Service Mathematics and Primary School Teachers' Design and Application of Mathematics Materials in Woodworking Workshops

Demet DENİZ YILMAZ[1], Ayça KARTAL[2]

[1]Department of Mathematics Education, Muş Alparslan University Faculty of Education, Muş, Turkey
[2]Department of Primary School Teaching Education, Muş Alparslan University Faculty of Education, Muş, Turkey

Abstract

This study addressed in-class activities with concrete mathematics (math) materials developed by preservice math and primary school teachers in woodworking workshops and investigated what preservice teachers and primary and secondary school students thought about lectures with those materials. The study employed an embedded mixed design, a predominantly quantitative approach. The sample consisted of 23 preservice math and primary school teachers and 30 secondary school and primary school students in Turkey. Quantitative data were collected using the Torrance Test of Creative Thinking Test. Qualitative data were collected using a Material Design Evaluation Rubric and a Semi-Structured Interview Form. The results showed that the woodworking workshops improved the figural creativity of the preservice math teachers and both the figural and verbal creativity of the preservice primary school teachers. The preservice teachers had no idea about what woodworking workshops were and had difficulty mostly with sandpapering and cutting. The primary and secondary school students stated that they enjoyed using the math materials and learned better. In line with the results of the research, it can be suggested that woodworking workshops be expanded not only in universities but also in primary and secondary schools.

Keywords: Math materials, preservice math teachers, preservice primary school teachers, wooden materials

Introduction

Every age has its unique type of human. The twenty-first century needs people who can cope with change (Erdem, 2020). The goal of literacy underlying 21st-century skills is more active participation and contribution to society (Gürbüz & Altun, 2016). The OECD (2020) defines mathematical literacy as "an individual's capacity to reason mathematically and to formulate, employ, and interpret mathematics to solve problems in a variety of real-world contexts." Mathematics (math) is more than an isolated and boring subject used merely to draw up a balance sheet; it is a living phenomenon more or less related to things around us (Pappas, 2014). Therefore, teachers should teach students that math is part of everyday life and more than the four operations. In particular, children should participate in activities that encourage them to think about math concepts and integrate them with other concepts, thereby improving relational understanding. From this perspective, math education aims to turn students into people who can not only do math but also put knowledge into practice, solve problems, and communicate, and are happy doing so (Olkun & Toluk, 2003). The question, "What general ideas will guide the way you will teach mathematics as you grow in the teaching profession?" (Van De Walle et al., 2018, p.1) brings to mind the quality of the opportunities and settings offered by teachers to encourage students to understand and learn math, in other words, to help them acquire math literacy. Settings where students acquire math literacy are more than just "places where math is learned" but involve all factors affecting learning (teacher, student, method and technique, materials, etc.) (Öztürk & Güven, 2012). Classrooms should have more educational materials to make students understand and learn better (Kurtdede-Fidan, 2008). Especially concrete materials enrich education and add depth to subjects, which in turn makes it easier for students to learn (Çelik, 2010). But the common problem, especially in elementary mathematics teaching, is that teachers have difficulties in accessing materials when they want to be innovative. Therefore, we need settings that allow us to prepare and use concrete materials, which are particularly useful for math class because they promote student involvement (Pişkin-Tunç et al., 2012) and enable students to better understand math concepts (Clements & McMillen, 1996). According to the National Council of Teachers of Mathematics [NCTM] (2000), teachers should use math materials to help students play a more active role in their own learning. Government agencies develop curricula and textbooks meticulously, but they do not have the same level of concern for educational materials and leave teachers to their own devices (Kaminski & Sloutsky, 2020, p. 1). Materials developed by teachers should promote creative and critical thinking and teacher-student interaction (Küçük-Demir, 2014). Educational materials that turn abstract math concepts into concrete forms improve students' creativity and critical thinking skills (Moyer, 2001). Therefore, faculties of education should offer a well-rounded education that analyzes the past, evaluates the present day, and improves future activities to turn students into math and primary school teachers who are capable of designing classrooms for effective math education (Bozpolat & Koç-Deniz, 2016; Tarım et al., 2017, p. 1048). Educational materials that turn abstract concepts into concrete forms can be real-life materials or specially designed (Van De Walle et al., 2018). The 2023 Education Vision of the Turkish Ministry

Corresponding Author: Ayça KARTAL, **E-mail:** a.kartal@alparslan.edu.tr

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Table 1.
Research Steps

Stages	Content	Time
QUAL Introduction, Data Collection, and Literature Review	QUAN + QUAL Results	October 2018–November 2018
QUAN + (qual) Data Collection and Intervention	Using the workshop tools and equipment to develop simple products (drawing product ideas on paper)	December 2018–January 2019
QUAN + (qual) Data Collection and Intervention	Making educational wooden materials and integrating them into lectures	February 2019–March 2019
QUAN + QUAL Data Collection and Intervention	Using the materials in primary and secondary schools	April 2019–May 2019
QUAN + QUAL Data Collection and Intervention	Receiving feedback, term evaluation, and posttest	May 2019–June 2019
QUAN + QUAL Data Analysis	Paired sample *t*-test, Wilcoxon, -content analysis	July 2019–November 2019
QUAN + QUAL Results	Interpreting the qualitative and quantitative results and finalizing the study	December 2019–March 2020

QUAN, quantitative methods; QUAL, qualitative methods.

of National Education approaches "design-skill workshops" from this perspective. It states that science, art, sports, and cultural activities in design-skill workshops should focus on occupational and manual skills to achieve shared goals for primary, secondary, and high school students (URL, 1). It also states that those workshops should be concrete venues that encourage students to develop 21st-century skills (problem-solving, critical thinking, productivity, teamwork, and multi-literacy skills). However, professional teachers are concerned about those workshops because they do not have enough experience (Gündoğan & Can, 2020). Teachers, preservice teachers, and students have negative views or fears about math because it is an abstract subject (Authors, 2015). Therefore, faculties of education should offer workshops to turn students into teachers who can hold workshops. It is an innovative option for teachers, prospective teachers, or students to develop concrete materials in woodworking workshops. They can use those materials not only to teach and learn math concepts but also to integrate them into fun activities and games to enrich math education. The rationale of this study was to identify and eliminate the infrastructural deficiencies of woodworking workshops in faculties of education to allow preservice teachers to develop and use their own wooden materials.

Research addresses the effects of concrete materials on math education (Herron & Foster, 2017; Kutluca & Akın, 2013; Poon & Wong, 2017; Yılmazer & Keklikci, 2015), effectiveness of materials based on realistic math education (Hasibuan et al., 2019), teachers' thoughts about using concrete materials in math education (Yazlık, 2018), the importance of developing materials for math education (Bozkurt & Akalın, 2015), primary school teachers' beliefs and expectations of concrete materials in math education (Gökmen et al., 2016), meta-analysis on the effects of educational materials on math performance (Kul et al., 2018), effectiveness of hands-on math activities at different grade levels (Magrone et al., 2019), effects of experimental materials on math performance (Mutmainah et al., 2019), preservice teachers' self-efficacy in using concrete materials in math education (Pişkin-Tunç et al., 2012), teachers' views on what makes math learning environments effective (Öztürk & Güven, 2012), and the use of learning objects in math education (Baki & Çakıroğlu, 2010; Kay & Knaack, 2008; Oliveira & Neto, 2019). However, there is no published research on preservice teachers designing materials and using them in real-life classroom settings. Therefore, the main research question of this study was, "What is the effect of mathematical materials designed in woodworking workshops on creativity?" Qualitative and quantitative data

Table 2.
Experimental Application Process

Date	Theme	Activities
October 2018–November 2018	Preparation for the project	Giving training to the project coordinator and researchers to use wood machines, which lasted about 1 week, by the company from which the machines were supplied.
October 2018–November 2018	Pretests	Pretests (Torrance Test of Creative Thinking) were administered to preservice teachers.
December 2018	Training for the use of machines	Trainings on how to install the machines, make a spinning top, cut, paint, and sandpaper were given to preservice teachers by the researchers.
January 2019–February 2019	Designing wooden materials and developing lesson plans	Preservice teachers were asked to design materials suitable for their achievements in the mathematics curriculum of their field. The preservice teachers shared with the researchers what kind of material they would prepare for each learning outcome, and as a result of the interviews, they decided what the draft materials would be.
February 2019–March 2019	Creating wooden materials and finalizing lesson plans	The preservice teachers developed the materials they designed in the woodworking workshop. Preservice math teachers have developed multiplication rings, fractions, tangrams, goniometers, number sets, and Napier's bones to be used in fifth–eighth grade classrooms. Preservice primary school teachers have developed subtraction tables, operations with rotating numbers, wooden numbers, I divided my apple, the game of smart corridor, and a train of operations to be used in first–fourth grade classrooms. The lesson plans in which they will use all these products were given their final form.
April 2019–May 2019	The use of wooden materials in primary and secondary schools	The prepared materials were evaluated according to the material design evaluation rubric, and their applications were made in schools, and the opinions of primary and secondary school students were taken.
May 2019–June 2019	Posttests	At the end of the application, Torrance Test of Creative Thinking was applied to the preservice teachers as a posttest, and the opinions of the preservice teachers and students were also taken.

Notes: TTCT = Torrance Test of Creative Thinking.

Table 3.
Skewness and Kurtosis Coefficients of Torrance Test of Creative Thinking Pretest and Posttest Scores of Preservice Math Teachers

Skewness and Kurtosis Coefficients	Mean	Skewness	Kurtosis
TTCT verbal creativity pretest	23.7949	1.448	2.175
TTCT verbal creativity posttest	32.5897	0.482	−0.371
TTCT figural creativity pretest	11.2615	−0.509	0.079
TTCT figural creativity posttest	14.0154	1.244	2.834

Note: TTCT = Torrance Test of Creative Thinking.

Table 4.
Skewness and Kurtosis Coefficients of the Torrance Test of Creative Thinking Pretest and Posttest Scores of the Preservice Primary School Teachers

Skewness and Kurtosis Coefficients	Mean	Skewness	Kurtosis
TTCT verbal creativity pretest	24.4524	0.179	−0.474
TTCT verbal creativity posttest	33.1905	−0.392	−0.047
TTCT figural creativity pretest	12.3857	0.590	−0.804
TTCT figural creativity posttest	15.3286	−0.381	−1.265

Note: TTCT = Torrance Test of Creative Thinking.

were collected and analyzed to answer the main question. Quantitative data were collected using the Torrance Test of Creative Thinking (TTCT) to seek answers to the following subquestions:

- Was there a significant difference between the TTCT pretest and posttest scores of preservice math teachers who attended the woodworking workshop?
- Was there a significant difference between the TTCT pretest and posttest scores of preservice primary school teachers who attended the woodworking workshop?

Qualitative data were collected using a Material Design Evaluation Rubric and a Semi-Structured Interview Form to seek answers to the following subquestions:

- What did preservice math teachers think about attending the woodworking workshop?
- What did preservice primary school teachers think about attending the woodworking workshop?
- What did secondary school students think about lectures with wooden materials?
- What did primary school students think about lectures with wooden materials?
- How did the woodworking workshops affect preservice math teachers' abilities to develop educational materials?
- How did the woodworking workshops affect preservice primary school teachers' abilities to develop educational materials?

Methods

Research Design

This study addressed in-class activities with concrete math materials developed by preservice math and primary school teachers in woodworking workshops and investigated what preservice teachers and primary and secondary school students thought about lectures with those materials. There are different mixed designs that integrate qualitative and quantitative data (Creswell, 2014; Fraenkel & Wallen, 2005). Creswell and Plano Clark (2014) define six types of mixed design: convergent parallel design, explanatory sequential design, exploratory sequential design, embedded design, transformative design, and multiphase design. The study employed an embedded mixed design, which is a predominantly quantitative approach. Embedded design embeds the qualitative stage into the quantitative stage to support the experimental data (Mertkan, 2015).

The quantitative stage involved a single-group pretest-posttest experimental design without random sampling or pairing (Çepni, 2014). The single-group experimental design was the method of choice because it allowed us to overcome internal validity problems, compensate for the lack of a control group, and interpret the results more clearly by supporting quantitative data with qualitative data (Cevher, 2015).

The qualitative stage was a case study, a research design that integrates different data collection techniques (interviews, observations, documentation, etc.) and goes beyond isolated variables and looks into the relationship between fact and context (Yin, 2018). A case study can be explanatory, exploratory, or descriptive (Gliner et al., 2015). The case study was the method of choice in the qualitative stage because it allowed us to use multiple sources and situations to evaluate participants' educational materials.

Sample

Participants were recruited using criterion sampling, a purposive sampling method. Criterion sampling is used to draw a sample that satisfies a set of predetermined criteria (Patton, 2014). As a criterion in the research, it was determined to have chosen an elective course, to have taken the material design course, and to have the skills to make a lesson plan. The study was conducted in the spring semester of the 2018–2019 academic year. The sample consisted of 11 students at the Primary School Mathematics Teaching Department, 12 students of Anonymous, as well as ten primary school students and 20 secondary school students in Anonymous/Turkey. Preservice math and primary school teachers were recruited because they have difficulty translating math concepts into concrete forms, developing positive attitudes towards math, and relating it to real life.

Data Collection Tools

Quantitative and qualitative data were collected together. The qualitative data was collected using the Material Design Evaluation Rubric (MDER) and Semi-Structured Interview Form (SSIF) developed by the researchers. The MDER was based on a literature review and consisted of the criteria of "Appropriate to the Outcome/Purpose," "Originality," "Attention-Grabbing," "Reusability," and Durability, responded to as Yes, No, Somewhat, Why, or Why not? The MDER was checked by experts (an academic specializing in math education and a math educator who conducts doctoral studies on primary school education). Separate SSIFs were developed for preservice teachers and students. They were appropriate to the level of the groups and consisted of clear and straightforward questions, which were checked by two experts conducting qualitative research (an academic with a Ph.D. degree in primary school teacher education and an academic with a Ph.D. degree in math education). A pilot study was conducted with a preservice teacher, a primary school student, and a secondary school student to check the intelligibility of the questions. Both questionnaires were revised and made ready for the main study.

The quantitative data was collected using the TTCT. The TTCT was developed by Paul Torrance. Aslan (2001) reported that the TTCT had a Cronbach's alpha (internal consistency) of 0.86–0.89 for primary schools and 0.83–0.84 for universities. Permission was obtained from Prof. Dr. Ayşe Esra ASLAN for TTCT training and implementation (date: March 6, 2015). The TTCT consists of two subtests: verbal (TTCT-V) and figural (TTCT-F). The TTCT-V consists of seven

Table 5.
Difference Between Preservice Math Teachers' Verbal Torrance Test of Creative Thinking-V and Figural Torrance Test of Creative Thinking Pretest and Posttest Scores

TTCT-V and TTCT-F Pretest and Posttest Scores	Z	p
Verbal Creativity Pretest- Verbal Creativity Posttest	−1.922	.055
Figural Creativity Pretest - Figural Creativity Posttest	−2.491	.013

Note: TTCT-V = Verbal Torrance Test of Creative Thinking; TTCT-F = Figural Torrance Test of Creative Thinking.

activities: asking, guessing causes, guessing consequences, product improvement, unusual uses, unusual questions, and just suppose. The TTCT-F consists of three activities: picture construction, picture completion, and parallel lines.

Data Collection

The supplier trained the project coordinator and the researcher for about a week on how to operate the workshop machines. First, the preservice teachers took the TTCT as a pretest and then were trained for five weeks (during elective courses) on how to install the machines, make a spinning top, cut, paint, and sandpaper. They were asked to design wooden materials appropriate to the math learning outcomes in the curriculum. For two weeks, they consulted with the researchers about what kind of materials to design and finally decided on draft materials. They made the designs themselves. The materials were evaluated using the MDER. The preservice teachers used the materials in their lectures in primary and secondary schools and then took the TTCT as a posttest. Afterwards, both preservice teachers and students were interviewed. Table 1 shows the research steps.

Experimental Application Process

In accordance with the application process described in Table 1, preservice mathematics teachers have developed multiplication rings, fractions, tangrams, goniometers, number sets, and Napier's bones to be used in fifth–eighth grade classrooms. Preservice primary school teachers have developed subtraction tables, operations with rotating numbers, wooden numbers, I divided my apple, the game of smart corridor, and a train of operations to be used in first–fourth grade classrooms. Information on the experimental application process is presented in Table 2.

Data Analysis

The quantitative data was analyzed using the Statistical Package for Social Sciences (SPSS, version 22.0) at a significance level of 0.05. The dependent group *t*-test and the Wilcoxon signed rank test were used for analysis. A dependent group *t*-test is used to determine within-group differences over one or more variables (Salkind, 2015). The prerequisites of TTCT showed that the data were discrete. Skewness and kurtosis coefficients of −1 to +1 indicate a normal distribution. The TTCT-V pretest and posttest data had skewness and kurtosis coefficients from −1 to +1 and were therefore analyzed using a paired-sample *t*-test, which is a parametric test. However, the TTCT-F pretest and posttest data did not have skewness and kurtosis coefficients from −1 to +1 and, therefore, were analyzed using the Wilcoxon signed rank test, which is the non-parametric counterpart of the paired-sample *t*-test.

Table 6.
Difference Between Preservice Primary School Teachers' Verbal Torrance Test of Creative Thinking Pretest and Posttest Scores

TTCT-V Scores	Mean	T	p
Pretest	24.4524	−5.188	.000
Posttest	33.1905		

Note: TTCT-V = Verbal Torrance Test of Creative Thinking.

Table 7.
Difference Between Preservice Primary School Teachers' Figural Torrance Test of Creative Thinking Pretest and Posttest Scores

TTCT-F Scores	Z	p
TTCT-F pretest-posttest	−2.412	.016

Note: TTCT-F = Figural Torrance Test of Creative Thinking.

Table 8.
Preservice Math Teachers' Views

Theme	Category	Code	Participants
Prior knowledge of woodworking workshops	Yes	Souvenirs (ornaments)	M3, M7
		On TV	M6, M10
		Furniture	M5
		The art of Naht (wood carving)	M9
		Public education courses	M11
	No	Never heard before	M1, M2, M4
		Never heard because there was none	M8
Target Skill	Skill	Dexterity	M1, M2, M5, M3, M9, M10
Challenging stages of the workshop	Wooden	Creative thinking	M2, M5, M10, M11
		Material development	M4, M6, M8
		Concentration	M7
		Cutting	M1, M2, M3, M5, M6, M7, M8, M10, M11
		Sandpapering	M4, M9
Thoughts about benefiting workshops	For teaching	Student-centered	M1, M2, M11
		Educational games	M3, M8, M10
	Making materials	Material development	M1, M5, M6, M7, M9, M11
	Individual	Thinking and developing	M4
Activities for secondary school students	Material	Course material	M2, M4, M5, M6, M7, M8, M9, M10, M11
		Educational games	M4, M8, M11
	Development	Creative thinking	M2
	Guidance	Dexterity	M2, M4
		Live and learn	M1, M8
		Guidance	M3
Expectation	Positive	Material development	M1, M4, M6, M7, M8, M9,
	Uncertain		
		Stress-free atmosphere	M3, M7, M10, M11
		None	M2, M5
Meeting expectations	Yes	Material development	M1, M4, M6, M8
		Creative thinking	M4, M5
		Dexterity	M5
	No	Hard	M7, M10, M11
	Exceeded		
		Insufficient material	M3, M9
		Beyond my expectations	M2,
Any suggestions for woodworking workshops	Yes	More material	M1, M8, M9, M11
		More lectures	M3, M7
		Should be offered by secondary schools	M4
	No	None	M2, M5, M6, M10

Table 3 shows the skewness and kurtosis coefficients of the TTCT pretest and posttest scores of the preservice math teachers.

Table 4 shows the skewness and kurtosis coefficients of the TTCT pretest and posttest scores of the preservice primary school teachers.

Table 9.
Preservice Primary School Teachers' Views

Theme	Category		Code	Participants
Prior knowledge of woodworking workshops	Yes		Did not use	C1, C2
			From social media	C7, C10
			Heard of it	C2, C8
			From friends	C11
			Never in school	C1
			Have been to workshops before	C9
	No		-	C3, C4, C6
			Not interested	C5
			Toys	C12
Target skill	Skill	Thinking	Creative	C1, C4, C9, C12
			Generating new ideas	C9, C10, C11
			In multiple areas	C5
			Critical	C1
			Using tools and equipment	C3, C8, C9, C11, C12
			Using wooden materials	C2, C4, C8, C10
			Hand	C1, C5, C9, C12
			Making one's own materials	C3, C7
			Being careful	C5
			Making the most of few materials	C6
			Teamwork	C8
Challenging stages of the workshop	Wooden		Cutting	C2, C5, C7, C8, C10, C12
			Forming/shaping	C1, C3, C4, C10, C12
			Making a spinning top	C9
	Shortage		Material	C8
	None		-	C14
Thoughts about benefiting from workshops	Making materials		Appropriate to the topic	C1, C6, C7, C8, C10
			For math	C2, C4, C12
			Durable	C3
	Individual		Increasing self-confidence	C5, C7
			Uncovering hidden talent	C5
	For teaching		Abstract concepts	C9
			Fun lecture	C5
	No		Takes too much time	C11
	Making materials		Appropriate to the topic	C1, C6, C7, C8, C10
Activities for primary school students	Material		Simple	C3, C5, C6, C7, C8, C9
			Toys	C1, C3, C4, C5
			Small house, trees	C2
			Puppet	C3
	Development		Imagination	C10, C11
			Dexterity	C11
	Have difficulty		Shaping/cutting	C10
	Activity		Any kind	C12

(*Continued*)

Table 9.
Preservice Primary School Teachers' Views (Continued)

Theme	Category	Code	Participants
Expectation	Positive	Curiosity/excitement	C6, C8
		Developing materials	C10, C11
		A large space full of materials and machinery	C5
		Learning to use tools	C3
		Taking knowledge to the next level	C9
		Learning a lot	C4
	Uncertainty	No knowledge/ expectations	C2, C3, C6, C8
	Negative	Fear of failure	C7
		Anxiety about not being able to use tools	C1
		Working with large parts	C12
Meeting expectations	Yes	Designing different materials	C10, C11
		Machines that do not break down	C7, C8
		Materials that are available	C8, C12
		I learned how to use tools and work the wood	C1, C3
		Enjoyable/fun	C4
		I have improved my weaknesses	C9
	No	Lack of material	C5
		Narrow space	C5
		A limited number of machines	C5
		It has got me thinking differently	C6
	Exceeded	Related to real life	C2
Any suggestions for woodworking workshops	Yes	Increased number and diversity of materials	C1, C5, C8, C10, C12
		Increased number and diversity of tools	C1, C5, C7, C8, C9
		They should be more common	C5, C8
		There should be more workshops	C2
		Portable tools should be used	C7
	None	-	C3, C4, C8, C11

Validity/Reliability-Credibility/Consistency

The quantitative data was analyzed using Statistical Package for Social Sciences version 22.0 (IBM SPSS Corp.; Armonk, NY, USA) at a significance level of 0.05. The dependent group *t*-test and the Wilcoxon signed rank test were used for analysis. Normality was tested before analysis.

Data diversification was used to check the credibility and consistency of the qualitative data. The material development process was evaluated using the MDER. Data diversity was achieved by interviewing both pre-service teachers and students. Participants were assigned codes to ensure

Table 10.
Secondary School Students' Views of Lectures with Wooden Materials

Theme	Category	Code	Participants
Having seen wooden educational materials before	No	-	All participants
Interested in wooden materials	Yes, I am	Educational	S7, S8, S9, S10, S11, S12, S14, S16, S17
		Nice colors and shapes	S2, S3, S4, 05, S13
		Something new	S15, S18, S20
		Curiosity	S6, S19
		Fun	S16
		Helped me understand the topic	S1
Educational features of wooden materials	Good	Fun	S3, S5, S6, S10, S11, S13, S18
		Geometric figures	S4, S7, S10, S12, S14
		I understood	S1, S15, S18, S20
		Multiplication - division	S2, S17, S19
		Fractions	S2
	No response		S8, S9, S10
Eagerness to design wooden materials	Positive	Understanding the topic	S2, S7, S8, S9, S10, S11, S12, S14, S15, 016, S17
		I would like to	S3, S5, 06, S18, S19, S2
		Unwinding, fun, enjoyable	S4, S13, 14
		I would like my friends to experience it too	S1
		I could do it better	S5
		Class participation	S11
Using wooden materials in math classes	Positive	Educational	S1, S2, S4, S6, S7, S8, S9, S10, S12, S13, S14, S15, S16, S17, S18, S20
		Enjoyable	S1, S3, S13, 016
		Limited opportunities	S5
		Loving math	S11
		Creative	S19
Any suggestions	Yes	Colorful	S12, S15, S18
		Bigger	S14, S15
		More figures	S8, S9
		Available in schools	S5, S20
		More participation	S6
		Could have been harder	S10
	None	-	S1, S2, S3, S4, S7, S11, S13, S16, S17, S19

confidentiality and protect their anonymity (M1, M2, M3, etc., for preservice math teachers; C1, C2, C3, etc., for preservice primary school teachers; S1, S2, S3, etc., for secondary school students; and P1, P2, P3, etc., for primary school students). The two researchers split the qualitative data in half: one coded one half, while the other coded the other half. The researchers exchanged the data sets and made modifications to the codes. For example, the theme of "prior knowledge of woodworking workshops," which was under one table in the first coding, was moved under the same table with other themes in the second coding. Similarly, the responses "yes" and "no" were reduced to "no" under the theme of "having seen wooden educational materials before" posed to secondary school students. Direct quotations were used to provide an accurate and coherent picture of the participants' views.

Limitations

The study had two limitations. First, the results are sample-specific and, therefore, cannot be generalized. Second, the preservice teachers designed and made wooden materials in groups of two or three.

Results

Quantitative Results

Results Regarding the First Subquestion

The first subquestion addressed preservice math teachers' creative thinking skills. Their TTCT-V and TTCT-F pretest and posttest scores were analyzed using the Wilcoxon signed ranks test (Table 5).

There was no significant difference between the preservice math teachers' TTCT-V pretest and posttest scores ($p$verbal = .055 > .05), but there was a significant difference between their TTCT-F pretest and posttest scores ($p$figural = .013 < .05). This result showed that the woodworking workshops improved the preservice math teachers' figural creativity but not verbal creativity.

Results Regarding the Second Subquestion

The second subquestion addressed the preservice primary school teachers' creative thinking skills. Their TTCT-V and TTCT-F pretest and posttest scores were analyzed using a paired t-test (Table 6).

The preservice primary school teachers had a significantly higher mean TTCT-V posttest score (33.1905) than the pretest score (24.4524) ($t(13) = -5.188$; $p = .00 < .05$).

The preservice primary school teachers' TTCT-F pretest and posttest scores were analyzed using the Wilcoxon signed rank test (Table 7).

There was a significant difference between the preservice primary school teachers' TTCT-F pretest and posttest scores ($p$figural = .016 < .05), indicating that the woodworking workshops improved their figural creativity.

Qualitative Results

Results Regarding the Third Subquestion

The third question investigated what the preservice math teachers thought about the woodworking workshops. Table 8 shows the results.

Table 11.
Primary School Students' Views of Lectures with Wooden Materials

Theme	Category	Code		Participants
Having seen wooden educational materials before	No	-		P1, P2, P3, P4, P8, P9
	Yes	At school		P6, P7, P10
		At my aunt's		P5
Interested in wooden materials	Interesting	It was nice		P3, P4, P6, P7, P9
		Colors		P1
		Shape		P2
		Bright		P5
		Never seen before		P8
		Fun		P10
Educational features of wooden materials	I learned	Fractions	Numerator, denominator, fraction bar	P3, P5
			Half, quarter	P4
			-	P1
		Multiplication	Multiplication table	P10
			-	P9
		Subtraction		P6, P7
		Division		P6
		Addition in my head		P8
		-		P2
Eagerness to design wooden materials	Positive		We learn how to subtract	P6, P7
			We learn how to add	P8
			We learn fractions	P3
			It would be nice	P2
			My math gets better	P9
			I will do it when I am a teacher	P10
	Negative		Hard	P1
			I am too young; I cannot do it	P4
			I do not know how to do it	P5
Using wooden materials in math classes	Positive		Very good	P3, P4, P8, P10
			Fun class	P1, P2, P9
			Learning better and easier	P5, P6, P7
Any suggestions	Yes		Should include other numbers as well	P6, P7
			Should include different colors as well	P9
			Should be bigger	P2
			We can use in other classes as well	P5
	None		-	P1, P3, P4, P8, P10

Table 12.
Distribution of Preservice Math Teachers' Materials

Preservice Teachers' Codes	Materials and Grade Levels
M10, M11	Multiplication ring (grade 5)
M2, M5	Fractions (grade 5)
M7, M8, M9	Tangram (grade 5)
M12, M13	Goniometer (grade 7)
M1, M6	Number sets (grade 8)
M3, M4	Napier's bones (grade 8)

The preservice math teachers' views of the woodworking workshops were collected under the themes of "prior knowledge of woodworking workshops," "target skill," "challenging stages of the workshop," "thoughts about benefiting workshops," "activities for secondary school students," "expectation," "meeting expectations," and "any suggestions for woodworking workshops." The theme of "prior knowledge of woodworking workshops" had two categories: "yes" and "no." Under the category of "yes" were the codes of "souvenirs (ornaments)" and "on TV." The theme of "target skill" consisted of the codes of "dexterity" and "creative thinking." Direct quotations from preservice math teachers:

M9: Yes, I did; I was watching videos of fretwork because I'm interested in the art of Naht." (Prior Knowledge of Woodworking Workshops/Yes, Art of Naht)

M11: "It helped me use creative thinking skills. It allowed me to imagine different things and make them real, and bump into different things while searching for things I want to do." (Target Skill/Skill, Creative Thinking)

M4: "Of course, I would like to use it. If the school had a woodworking workshop or a woodworking workshop that I knew of, I would like to use it to help my students develop logical and mental skills." (Thoughts about Benefiting Workshops/Individuals, Thinking, and Developing)

Results Regarding the Fourth Subquestion

The fourth question looked into what the preservice primary school teachers thought about the woodworking workshops. Table 9 shows the results.

The preservice primary school teachers' views of the woodworking workshops were collected under the themes of "prior knowledge of woodworking workshops," "target skill," "challenging stages of the workshop," "thoughts about benefiting workshops," "activities for secondary school students," "expectation," "meeting expectations," and "any suggestions for woodworking workshops." The theme of "prior knowledge of woodworking workshops" consisted of the categories "yes" and "no." Under the category of "yes" were the codes "did not use" and "from social media." The theme of "target skill" consisted of the codes of "creative thinking," "using tools," and "equipment." Direct quotations from preservice primary school teachers:

C12: "I think it helped me develop creative thinking skills and also manual skills. I would never have imagined myself cutting wood, but now I love doing it. I think that it was a well-rounded activity." (Target Skill/Skill, Creative thinking)

C11: "I'd heard about woodworking workshops before, but I'd never seen one. A friend of mine from engineering was talking about it." (Prior Knowledge of Woodworking Workshops/Yes, From Friends)

C6: "I didn't have much expectation, but I was curious about woodwork." (Expectation/Uncertainty, No Knowledge/Expec tations)

Table 13.
Material Design Evaluation Rubric Evaluation of Preservice Math Teachers' Materials

Criteria	Yes	No	Somewhat	Explanation
Appropriate to the outcome/purpose	Fractions, tangram, goniometer, number sets		Multiplication ring and Napier's bones	The multiplication ring and Napier's bones were not about the learning outcomes but relied on students' prior knowledge.
Originality	Goniometer	Napier's bones, Fractions	Multiplication ring, Tangram, Number sets	The wooden materials about Napier's bones and fractions were not original. All materials except the goniometer were student-specific versions of already existing materials.
Attention-grabbing	Multiplication rings, fractions, tangram, goniometer, number sets, Napier's bones			All wooden materials were interesting.
Reusability	Tangram, goniometer, number sets, Napier's bones	Multiplication ring	Fractions	The multiplication ring had certain numbers, and therefore, it was impossible to operate with different numbers. The wooden materials about fractions were somewhat reusable because there was the risk of their pieces being lost.
Durability	Multiplication rings, fractions, tangram, goniometer, number sets, Napier's bones			All materials were quite durable because they were made of wood.
Grade-level appropriate	Fractions, tangram, goniometer, number sets, Napier's bones		Multiplication ring	The multiplication ring had very small numbers.

C10: "I thought cutting wood and giving it a shape would be easy, but it wasn't it was tiring. It's hard to sandpaper a piece of wood that's been cut crooked; it takes a lot of patience." (Challenging Stages of the Workshop/Wooden, Cutting)

Results Regarding the Fifth Subquestion

The fifth question focused on what the secondary school students thought about lectures conducted with the preservice teachers' wooden materials. Table 10 shows the results.

The secondary school students' views of lectures with wooden materials were grouped under the themes of "having seen wooden educational materials before," "interested in wooden materials," "educational feature of wooden materials," "eagerness to design wooden materials," "using wooden materials in math classes," and "any suggestions." The themes showed that the secondary school students had never seen wooden materials before. The theme of "interested in wooden materials" contained the category of "Yes, I am," which had the code of "educational." The theme of "educational features of wooden materials" contained the category of "good" with a code of "fun." Direct quotations from secondary school students:

S1: "Yes, I am interested in it. I'd never seen it before; it has helped me understand the topic better." (Interested in Wooden Materials/Yes, I am, Helped Me Understand the Topic)

Table 14.
Distribution of Preservice Primary School Teachers' Materials

Preservice Teachers' Codes	Materials and Grade Levels
C8, C10	Subtraction table (grade 1)
C6, C3, C4	Operations with rotating numbers (grade 1)
C2, C11	A train of operations (grade 1)
C14, C12	Wooden numbers (grade 2)
C1, C5, C16	I divided my apple (grade 3)
C7, C13	The game of smart corridor (grade 4)

S13: "Yes, I would definitely do it, to have fun, and to learn math better. I could use different methods to solve math problems." (Eagerness to Design Wooden Materials/Positive, Unwinding, Fun, Enjoyable)

S15: "The materials could have been bigger, more colorful and more attractive." (Any Suggestions /Yes, should be Colorful)

Results Regarding the Sixth Subquestion

The sixth question addressed the primary school students' views on lectures with wooden materials. Table 11 shows the results.

The primary school students' views of lectures with wooden materials were categorized under the themes of "having seen wooden educational materials before," "interested in wooden materials," "educational feature of wooden materials," "eagerness to design wooden materials," "using wooden materials in math classes," and "any suggestions." The theme of "having seen wooden educational materials before" consisted of the categories "no" and "yes." The theme of "interested in wooden materials" had the category of "interesting," with the codes "it was nice" and "colors." The theme of "educational feature of wooden materials" included the category of "I learned," with the codes of "fractions" and "multiplication." Direct quotations from primary school students:

P5: "I learned fractions and the numerator and denominator." (Educational Features of Wooden Materials/I Learned, Fractions, Numerator, Denominator, Fraction Bar)

P2: "Yes, it would be very nice. Ma'am let's have them [wooden materials] in every class, please. It's so much fun; we could play with them all the time; besides, it doesn't stop us from having class anyway." (Using Wooden Materials in Math Classes/Positive, Fun Class)

P9: "Yes, I definitely would. It helped me learn math better." (Eagerness to Design Wooden Materials/Positive, My Math Gets Better)

Table 15.
Material Design Evaluation Rubric Evaluation of Preservice Primary School Teachers' Materials

Criteria	Yes	No	Somewhat	Explanation
Appropriate to the outcome/ purpose	Subtraction table, operations with rotating numbers, wooden numbers, I divided my apple, the game of smart corridor, and a train of operations			All materials were about the learning outcomes, allowing students to use their prior knowledge.
Originality	Subtraction table, wooden numbers, I divided my apple, the game of smart corridor, and a train of operations		Operations with Rotating Numbers	The wooden material called "Operations with Rotating Numbers" about addition and subtraction was not original. Other materials were original, encouraging students to use their creativity.
Attention-grabbing	Subtraction table, operations with rotating numbers, wooden numbers, I divided my apple, the game of smart corridor, and a train of operations			All materials were interesting.
Reusability	Subtraction table, operations with rotating numbers, wooden numbers, I divided my apple, the game of smart corridor, and a train of operations			All materials were reusable.
Durability	Subtraction table, operations with rotating numbers, wooden numbers, I divided my apple, the game of smart corridor, and a train of operations			All materials were quite durable because they were made of wood.
Grade-level appropriate	Subtraction table, operations with rotating numbers, wooden numbers, I divided my apple, the game of smart corridor, and a train of operations			All materials were grade-level appropriate.

Results Regarding the Seventh Subquestion

The seventh subquestion focused on the MDER evaluation of the wooden materials designed by the preservice math teachers in groups of two or three. Table 12 shows the distribution of the materials.

The preservice math teachers' materials were analyzed using the MDER. Table 13 shows the results.

Only one group had an original material that satisfied all the criteria. The materials made by half of the preservice teachers were modified versions of already existing math materials. Some preservice teachers even tried to make exactly the same materials. All the wooden materials were durable and attention-grabbing.

Results Regarding the Eighth Subquestion

The eighth subquestion focused on the MDER evaluation of the materials designed by the preservice primary school teachers in groups of two or three. Table 14 shows the distribution of the materials.

The preservice primary school teachers' materials were analyzed using the MDER. Table 15 shows the results.

All materials made by the preservice primary school teachers were goal/outcome oriented. Only one group had a somewhat original material, while the other groups had original materials. They were all interesting, reusable, durable, and grade-level appropriate.

Discussion and Conclusion

This study evaluated the use of concrete materials made by preservice teachers in woodworking workshops for education. The first and second subquestions addressed the effect of the woodworking workshops on the preservice teachers' creative thinking skills. The results showed that the woodworking workshops significantly improved their verbal creativity but not their figural creativity. However, the preservice teachers stated that the woodworking workshops improved their verbal and figural creativity, which is believed to be due to their experiences with the design process, helping them develop different perspectives and creative thinking skills. It takes students great effort, discussion, and critical thinking to develop creative thinking skills (Eisner & Ecker, 1966; Kırışoğlu, 2005; San, 1993; Schon, 1995). However, creativity is also about the situation one is in (Adams, 2001; San, 1993; Young, 1985). Our results showed that the woodworking workshops improved the preservice teachers' creativity, involving both effort and coincidence, because they did not give up despite the limited number of machines and materials and tried their best and completed the workshops. Also, with the practice-based teacher education innovations in woodworking workshops, preservice teachers were able to produce their own materials and find the opportunity to present them in schools.

The third and fourth subquestions focused on what the preservice teachers thought about the woodworking workshops. The results showed that some preservice teachers had no idea about woodworking workshops, while others did. Some of those who had some idea about woodworking workshops stated that they had just heard about them but did not really know what they were all about. Therefore, neither preservice math nor primary school teachers knew much about woodworking workshops before participating in this study. This is because theoretical or applied courses offered by faculties of education do not provide any information about woodworking workshops and because woodworking is mostly associated with games and toys. Research on material design courses offered by faculties of education addresses students' self-efficacy and technological pedagogical content knowledge (Bakaç & Özen, 2016) and their attitudes towards and thoughts about those classes (Çalışoğlu, 2015; Öztürk & Zayimoğlu-Öztürk, 2015; İnağ-Çenberci & Yavuz, 2018). On the other hand, some studies look into the effect of hand-made and technology-based materials on creativity, but they focus mostly on stationery items and computer-based materials (Yanpar et al., 2006). Therefore, we can state that only a handful of studies tackle woodworking workshops. Our results also showed that the workshops improved the preservice math teachers' creativity, dexterity, concentration, and material design skills.

The preservice primary school teachers also stated that the workshops helped them learn how to use tools and equipment, develop materials, and collaborate. Research also shows that materials in workshops and lessons improve students' dexterity and creativity and help them develop different perspectives (Gündoğan & Can, 2020; Hasibuan et al., 2019; Ng & Ferrara, 2020). In short, the woodworking workshops helped the preservice teachers develop different types of skills. Güven and Karataş (2004) also argue that different teaching designs promote math learning because education in different settings allows students to put theory into practice. The preservice teachers had difficulty in sandpapering and cutting, which is probably because it was the first time they had participated in such workshops and used tools and equipment. They stated that they would like to use what they learned in the workshops in their own lectures in professional life. They noted that they would like to integrate appropriate and durable materials into student-centered and educational games to achieve learning retention and help their students build up self-confidence. Magrone et al. (2019) also argue that concrete materials positively impact learning. The woodworking workshops were productive for the preservice teachers in terms of both practice and theory. The preservice math teachers stated that they thought of woodworking workshops as an artistic activity. Therefore, we can state that woodworking workshops are an artistic and interdisciplinary activity. The preservice teachers had aesthetic concerns when deciding what color and shape of materials to design. Nutov (2018) remarks that activities that integrate math and art help students understand math better. However, some of the preservice primary school teachers had no idea about what to do in the workshops, while others were concerned about using the tools and afraid of failing. This is probably because they were both excited and nervous about doing something they had never done before. However, they stated that the workshops met their expectations, with the only setback being that there were too few tools. This was because the workshops were too crowded. Therefore, the preservice teachers suggested that there be more woodworking workshops with more tools and space.

The fifth and sixth subquestions addressed what the primary and secondary school students thought about lectures conducted with the preservice teachers' wooden materials. The secondary school students stated that it was the first time they saw such materials used in classes, but they enjoyed it and learned better. They also noted that they would like to design such materials and use them in lectures. Kaminski and Sloutsky (2020) also argue that students who use their own materials in lectures are likely to learn better. The primary school students also found the lessons enjoyable and easy to learn, especially the four operations, and stated that they would like to use such materials in other classes as well. Kösece and Taşkaya (2015) also highlight the significance of math labs' and tools and materials to turn abstract math concepts into concrete forms for effective learning.

The seventh and eighth subquestions evaluated the preservice teachers' materials. Most preservice math teachers made modified versions of existing materials, while most preservice primary school teachers developed original materials, confirming the TTCT-F results.

Recommendations

Faculties of education should collaborate with vocational high schools to set up workshops where students can design their own materials and use them in their lectures. Students should be encouraged to come up with original materials in woodworking workshops. This would not only improve their creativity but also make the process more economical and autonomous. A "Pool of Wooden Materials" should be developed to support primary and secondary schools. Not only preservice math teachers but also students of other departments should attend woodworking workshops and create their own educational materials. Therefore, faculties should provide academics with training on how to operate workshop machines.

- Not only universities, but also primary and secondary schools, should hold woodworking workshops. Faculties of education and the Ministry of National Education should collaborate to develop "Design-Skill Workshops."
- Material design courses offered by faculties of education should also hold applied woodworking workshops for no more than ten students. Academics should collaborate with consultants to perform those workshops. Primary and secondary schools should have math laboratories, for which preservice teachers design materials.
- The results of this study are limited to primary and secondary school students and preservice class and math teachers in Mus and Turkey. Future studies should focus on preservice teachers from different cities or branches. They should also recruit teachers from different branches and train them in woodworking workshops. Our participating preservice teachers developed only one material in the workshops. Future studies should ask preservice teachers to develop more materials in workshops to look into different skills (inquiry, critical thinking, etc.).
- This study was conducted before the coronavirus 2019 pandemic. Therefore, future studies should focus on developing online woodworking workshops integrated with augmented reality or virtual reality to overcome the challenges of the pandemic.

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