

Article

The Effect of Sustainability-Based Microteaching Practices on the Beliefs and Pedagogical Reflections of Primary School Mathematics Teacher Candidates

Mehtap Tastepe 

Program of Primary School Mathematics Teaching, Department of Science and Mathematics Education, Faculty of Education, Sinop University, Sinop 57000, Türkiye; mtastepe@sinop.edu.tr

Abstract

This study investigated the impact of preparing lesson plans and conducting microteaching activities—aligned with the learning outcomes of the mathematics curriculum—on the development of sustainability beliefs among teacher candidates. The rationale behind this research stems from the growing global emphasis on sustainability and the urgent need to embed sustainability literacy into teacher education programs, particularly in disciplines such as mathematics, which are often perceived as abstract and value-neutral. There is a recognized gap in equipping pre-service teachers with the pedagogical skills and conceptual awareness needed to integrate sustainability meaningfully into mathematics instruction. Employing a mixed-methods design, the Sustainability Belief Scale was administered to 45 teacher candidates (22 in the experimental group and 23 in the control group) as both a pre-test and post-test. During the intervention, participants in the experimental group collaboratively designed lesson plans and delivered them through microteaching sessions. Throughout the process, they maintained individual reflective journals. The lesson plans and microteaching performances were evaluated using instructor-developed rubrics. Data were analyzed using both quantitative statistical techniques and qualitative content analysis. The findings indicate that integrating sustainability themes into mathematics education significantly enhances teacher candidates' sustainability beliefs and informs their pedagogical orientations. This study underscores the importance of structured, practice-based learning experiences—such as sustainability-focused microteaching—as a means to develop the competencies needed for education for sustainable development in mathematics classrooms.



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Keywords: sustainability; primary school mathematics teaching; microteaching; lesson plan; reflective journal; assessment rubric

1. Introduction

Problems such as the climate crisis, biodiversity loss, resource depletion, and social inequalities that the world is currently facing have transformed the concept of sustainability into a multidimensional issue that extends beyond environmental concerns. In this context, sustainability represents a holistic approach that must be addressed together with its environmental, social, cultural, and economic dimensions. The concept of sustainable development aims to use resources in a manner that does not jeopardize the lives of future generations, to achieve sustainable growth, to protect nature, and to ensure that all people attain the quality of life they deserve—in short, to make the world more livable [1,2].

Therefore, educating individuals about sustainability has become essential to embedding this understanding effectively [3]. Sustainability literacy is gaining increasing traction as societies confront urgent environmental challenges; individuals must adapt their mindsets and unsustainable lifestyles to influence their thoughts, decisions, and actions in response to these challenges [4,5]. Education plays a crucial role in fostering this multidimensional awareness and translating it into concrete behavior.

In the literature, the relationship between sustainability and education is addressed from two main perspectives. The first approach is based on education for sustainable development and emphasizes practices based on a progressive education approach that aims to help students think about real-life problems and develop experiential learning and problem-solving skills [6,7]. The second approach focuses on sustainable education; this perspective expresses a radical paradigm shift that aims to help individuals understand social, economic, and ecological systems, develop behaviors appropriate to these systems, and transform their lifestyles accordingly [8–11].

Mathematics education plays a strategic role in providing the skills necessary for sustainable living, such as critical thinking, modeling, systemic perspective, and especially problem-solving. However, the integration of sustainability into the mathematics curriculum is still limited. For example, Jablonka (2003) [12] states that by examining the relationship between mathematical literacy and society, social themes such as sustainable development are not adequately represented in the curriculum. Similarly, Sriraman and English (2021) [13] while revealing the potential of integrating systems thinking and sustainability in the context of Science, Technology, Engineering, and Mathematics (STEM) education, indicates that this integration has not yet been systematized at the curriculum level. At this point, prospective teachers need to adopt sustainability-focused pedagogical approaches and reflect this in their teaching plans. Moreover, the integration of sustainable development education not only into curriculum but also into teacher training processes has become a necessity on a global scale. This situation has become even more crucial with the recognition of the key role teachers play in social transformation. For example, in England, various structural changes have been made to teacher training programs with the idea that teachers equipped with sustainable development and global citizenship will be decisive in achieving society's long-term sustainability goals [14,15]. Similarly, in Germany, sustainable development education has been adopted as a national strategy in cooperation with the Standing Conference of Ministers of Education and Culture (KMK) and the Federal Ministry for Economic Cooperation and Development (BMZ), and a theoretical and practical framework program covering all levels of education has been created [16].

This study examined the impact of sustainability-focused microteaching practices on preservice teachers' beliefs and pedagogical approaches. One of the unique aspects of this study is that it specifically addresses this process within the context of mathematics education. This discipline-focused approach reflects not only a thematic preference but also a pedagogically meaningful orientation.

Mathematics is a subject area with the potential to develop higher-order cognitive skills such as abstract thinking, modeling, problem solving, and analytical reasoning. Sustainability, on the other hand, is a multidimensional concept requiring individuals to understand the complex relationships among environmental, economic, and social systems. In this context, the nature of mathematics that supports critical thinking and systems analysis skills is considered an important tool for acquiring sustainability concepts through education.

Developing the knowledge, attitudes, and awareness of preservice elementary mathematics teachers on how to convey sustainability through their own disciplines is crucial for enhancing their professional competence. Therefore, focusing on mathematics teaching

was chosen in this study to ensure that sustainability is not only a general awareness but also integrated and embodied in interdisciplinary teaching practices. Thus, the reflection of sustainability education on the pedagogical practices of prospective teachers could be evaluated in a more meaningful and functional way. The purpose of this study is to examine the reflections of sustainability-focused microteaching practices on the beliefs and pedagogical approaches of primary school mathematics teacher candidates regarding sustainability. This study aims to contribute to the teacher training process in terms of sustainability literacy.

Importance of Research

Sustainable development is a multidimensional concept that has become a central focus within contemporary education systems. In this context, equipping teacher candidates with sustainability awareness will enable teachers, who are the main actors of social transformation, to contribute to this process. Understanding the beliefs about sustainability and the reflections of these beliefs on the teaching process, especially in disciplines such as mathematics education, both increases the quality of teacher education programs and contributes to the strengthening of the interdisciplinary sustainability approach. Microteaching practices provide teacher candidates with experiences similar to those in the real classroom environment, allowing them to structure their pedagogical knowledge and skills. The reflective journals and evaluation rubrics used in this process allow candidates to critically evaluate their own teaching processes and realize the extent to which they reflect their understanding of sustainability in their teaching. In this context, examining the effects of sustainability-focused micro-teaching practices on the beliefs and pedagogical approaches of teacher candidates will make significant contributions to both the teacher education literature and the practical aspect of sustainability education.

2. Theoretical Framework and Literature Review

2.1. Sustainability Beliefs: Definition and Measurement

Sustainability beliefs refer to the convictions that individuals hold, acknowledging their role in taking individual and social responsibility for a sustainable world. These beliefs guide attitudes and behaviors [3,17]. Various scales have been developed in the literature to measure these beliefs. Recent studies have revealed that developing the sustainability beliefs of prospective teachers is critically important in terms of both individual awareness and professional responsibility. Zeichner and Bier (2019) [18] stated that while prospective teachers exhibit a high level of belief in sustainable lifestyle behaviors, these beliefs do not always translate into actual behavior. Similarly [19], it was determined that prospective teachers' perceptions of sustainability were mostly limited to the environmental dimension and that social and economic dimensions were not given enough space. Özsoy (2012) [20] stated that sustainability beliefs have significant relationships with environmental knowledge and attitudes, but a holistic sustainability approach has not yet been established. Similar results are also seen in studies conducted at the international level. For example, Ardoin, Bowers and Gaillard (2020) [21] drew attention to the importance of experiential and interactive learning environments so that environmental education can positively affect individuals' beliefs. Boeve-de Pauw and Van Petegem (2017) [22] showed that school policies and teaching methods directly affect student beliefs. These findings indicate that sustainability beliefs should be addressed with a structured and multidimensional approach in teacher education programs.

2.2. Sustainability-Focused Planning in Mathematics Education

In recent years, the concept of sustainability has gained increasing importance in the field of mathematics education and has been incorporated into teacher training programs. Skovsmose (2020) [23] emphasized the role of mathematics education in building a sustainable society, drawing attention to ethically based mathematical modeling in the context of uncertainty; Sriraman and English (2021) [13] presented a theoretical framework by establishing the connections between systems thinking, STEM education, and sustainability. Planning and conducting sustainability-oriented mathematics courses has become increasingly important, particularly in the education of prospective teachers. Ardoin, Bowers and Gaillard (2020), Boz and Boz (2021) and Darmawan, Sarwan, Jatmiko and Patahuddin (2023) [21,24,25] examined the pedagogical content knowledge of prospective teachers within the context of sustainability and demonstrated how such integration influences their teaching competencies. Microteaching stands out as an effective tool at this point; it enables prospective teachers to both adapt sustainability-based content to the classroom environment and develop their pedagogical skills [26,27]. Findings in the literature generally show that sustainability-based teaching practices contribute positively to the professional development, mathematical thinking styles, and environmental awareness of prospective teachers.

2.3. Microteaching and Its Role in Teacher Training

Nowadays, microteaching practices in teacher training programs are recognized as an effective teaching strategy to enhance the professional competence of prospective teachers. Studies conducted especially in the context of mathematics teaching show that microteaching makes significant contributions to the development of both pedagogical content knowledge (PCK) and mathematical communication skills of prospective teachers [28,29]. These practices enhance candidates' ability to present mathematical concepts in a clear, understandable, and student-level manner, while also strengthening their capacity to recognize diverse student thinking styles [30]. It has also been demonstrated that microteaching processes enhance the self-efficacy beliefs of prospective teachers and increase their confidence in mathematics lessons [31]. Thanks to the structured, short-term, and observable teaching experiences offered by microteaching, candidates have the opportunity to evaluate and improve their teaching practices with the feedback they receive from their peers and faculty members [32].

Microteaching practices also stand out as an effective method for developing reflective thinking skills of prospective teachers. Studies conducted in different contexts reveal that microteaching provides prospective teachers with the opportunity to evaluate their own teaching processes critically, gain pedagogical awareness, and build their professional identities [33,34]. In this process, tools such as video recordings, peer feedback, and guidance counselor comments deepen reflection and enable candidates to analyze their teaching experiences in a multifaceted way [35,36].

In recent years, the use of rubrics in the evaluation of microteaching practices has become increasingly widespread. While rubrics provide an opportunity to evaluate the teaching process of prospective teachers in a multidimensional way, they also offer a more transparent, structured, and feedback-friendly system for learning objectives [37]. In the literature, findings that rubric-supported microteaching practices increase the self-evaluation, reflective thinking, and pedagogical awareness levels of prospective teachers are prominent [38,39]. In particular, the use of reflective journals and rubrics together helps candidates develop a more analytical and critical perspective on teaching activities. It is also stated that rubrics support multifaceted development by ensuring that teaching performance is not limited to content transfer but is also evaluated in different dimen-

sions, such as classroom management, student interaction, and material use [40]. In this context, the use of rubric-based measurement tools for the systematic and holistic evaluation of microteaching processes is viewed as a crucial tool in enhancing the quality of teacher education.

2.4. Research Problem

What kind of change is observed in the sustainability-related beliefs and pedagogical approaches of primary school mathematics teacher candidates during the sustainability-focused microteaching practices? How can this change be explained with reflective diaries and rubric evaluation data? In accordance with this problem, the following research questions were sought to be answered.

- How do sustainability-focused microteaching practices affect pre-service teachers' beliefs about sustainability?
- How do reflective journals reveal pre-service teachers' perceptions of sustainability and their reflections on their teaching processes?
- Which pedagogical elements stand out in the sustainability-based mathematics lesson plans prepared by pre-service teachers?
- How effectively do the assessment rubrics employed in the microteaching process reflect the degree to which pre-service teachers incorporate sustainability principles into their instructional design and teaching strategies?

3. Materials and Methods

3.1. Research Model

This research employed a mixed-method design, combining both quantitative and qualitative approaches. The mixed-method approach enables a more comprehensive understanding of the research problem by drawing on the generalizability of quantitative data and the depth of qualitative insights, particularly in cases where a single method may prove insufficient [41]. In this study, a concurrent mixed-method design was adopted, whereby quantitative and qualitative data were collected and analyzed simultaneously in a coordinated manner. The concurrent design was preferred because it allows for comparative interpretations by collecting both types of data in parallel, and provides a holistic understanding of interactive processes, especially in educational research [42,43].

In order to foster a lasting awareness of sustainability literacy in preservice teachers, theoretical knowledge and implementation processes must be addressed in a holistic manner. In this context, mixed methods research reveals measurable progress with quantitative data while providing in-depth information about preservice teachers' experiences, perceptions, and pedagogical reflections through qualitative data [44–47]. Studies conducted with explanatory sequential mixed designs, in particular, provide the opportunity to evaluate multidimensionally how microteaching sessions with sustainability themes are internalized [48,49]. International studies also reveal that the dissemination of sustainability education through micro-level practices in teacher training programs not only increases the pedagogical competencies of prospective teachers but also contributes significantly to developing social awareness [50].

In this context, the Sustainability Belief Scale was used as quantitative data to determine changes in the sustainability beliefs of prospective teachers. The reflective journals and rubric evaluation forms were analyzed as qualitative data sources to examine reflections on their pedagogical approaches. The data were analyzed separately, and the findings were compiled and interpreted in a comparative manner. This methodological integration enhances the reliability and validity of the research, enabling a multifaceted analysis of complex educational phenomena [51].

3.2. Participants

This study was conducted with 45 third-year teacher candidates enrolled in a primary school mathematics teaching program at a state university, including 22 in the experimental group and 23 in the control group. Participants were selected on a voluntary basis and consisted of individuals who had not previously received any training related to sustainability. However, the participants had previously taken courses such as teaching numbers and operations, teaching geometry and measurement, activity development, microteaching applications, etc., and within the scope of these courses, they prepared lesson plans and implemented microteaching and evaluated and were evaluated through different rubrics. Teacher candidates in the experimental group were coded as EPT1, EPT2, . . . , EPT22, while those in the control group were coded as CPT1, CPT2, . . . , CPT23.

3.3. Data Collection Tools

Self-Efficacy Belief Scale for Education for Sustainable Development: The scale, consisting of 13 items on a 5-point Likert type, was originally developed by [52] and adapted into Turkish by [53]. It was administered to both the experimental and control groups before and after the microteaching applications.

Lesson Plans: Pre-service teachers were asked to prepare lesson plans that were developed in groups and establish a sustainability context with the achievements in the mathematics curriculum.

Microteaching Practices in this study were designed as structured, small-scale teaching simulations in which pre-service mathematics teachers collaboratively prepared and implemented lesson plans that integrated sustainability themes into the mathematics curriculum. These sessions took place in a controlled, peer-based environment and served as a practical platform for candidates to experiment with instructional strategies that reflect sustainability principles—such as environmental awareness, resource consciousness, and value-based decision-making. During the microteaching process, each group presented their lesson to their peers as if teaching an actual classroom, while the rest of the cohort and the instructor observed and provided feedback based on a rubric developed to assess both pedagogical effectiveness and the integration of sustainability content. These practices not only allowed candidates to refine their teaching techniques through iterative feedback and reflection but also enabled them to explore how mathematical concepts like volume, area, or natural numbers can be connected meaningfully to real-world sustainability issues. The microteaching sessions were recorded and analyzed to assess teaching quality, material use, classroom management, and the coherence between sustainability objectives and instructional design.

Reflective Journals: Teacher candidates were asked to keep a reflective journal about their microteaching practices. For this purpose, a reflective journal template was prepared and given to the teacher candidates.

Rubrics: Rubrics were prepared and applied to evaluate the lesson plans and microteaching presentations.

3.4. Application Process

First, a pre-test was administered to the teacher candidates. Then, the students in the experimental group were divided into five groups, and the groups planned the mathematical acquisition they had determined in a sustainability-based manner. Then, each group presented their plan to the other candidates and conducted microteaching. The participants wrote a reflective diary at the end of their microteaching practices. Lesson plans and microteaching presentations were evaluated with rubrics. A post-test was applied at the end of the process. The application process is shown in Figure 1.

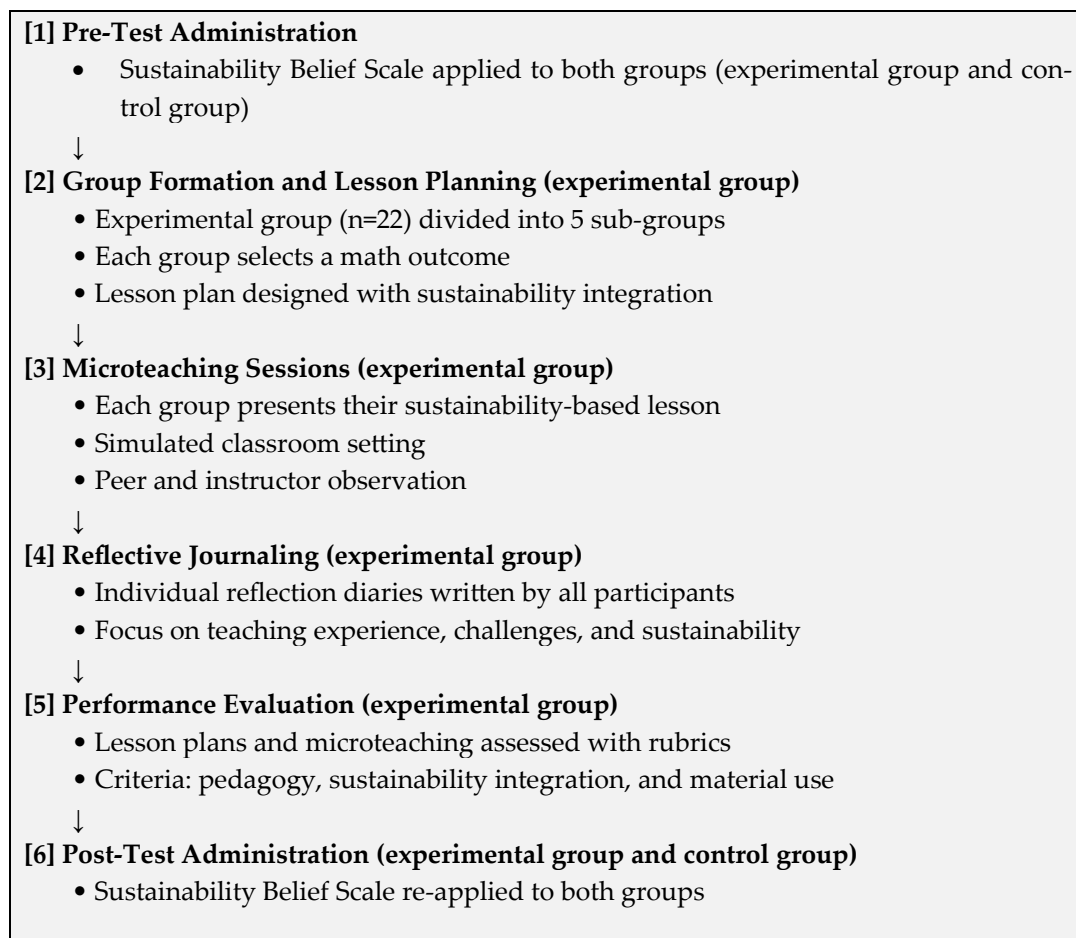


Figure 1. The sequential steps followed during the implementation of the sustainability-based microteaching intervention applied to the experimental group.

3.5. Data Analysis

In this study, the research questions were comprehensively addressed through both quantitative and qualitative data analyses. To investigate the impact of sustainability-focused microteaching practices on pre-service teachers' beliefs about sustainability, the "Sustainability Belief Scale" was administered as a pre-test and post-test. The quantitative data obtained were analyzed using SPSS (Version 3.1., IMB, New York, NY, USA); group means were compared, and the significance of the findings was tested through ANOVA and Levene's test. To explore pre-service teachers' perceptions of sustainability and their reflections on the teaching process, reflective journals kept throughout the implementation were utilized as a qualitative data source. These journals were analyzed using content analysis, and the codes and themes derived from the data were finalized in consultation with two mathematics education experts to enhance validity and reliability. The third research question aimed to identify the pedagogical elements that stood out in the sustainability-based mathematics lesson plans designed by the pre-service teachers. For this purpose, both the lesson plans and the microteaching presentations were evaluated using instructor-developed rubrics, and frequencies and means were calculated for each dimension. In addition, the instructional strategies and connections to sustainability within the plans were examined qualitatively. Finally, the fourth research question focused on the extent to which the assessment rubrics used during the microteaching process effectively reflected the pre-service teachers' integration of sustainability principles into their instructional design. To this end, rubric data were interpreted using descriptive statistics, offering a

holistic evaluation of the participants' sustainability-oriented teaching competencies. This framework ensured that both quantitative and qualitative data were directly aligned with the study's research questions.

3.6. Validity and Reliability

In this study, multiple data sources and methods were employed to ensure the validity and reliability of the research findings through data triangulation. Quantitative data were obtained through the Sustainability Belief Scale, and both pre-test and post-test scores were analyzed using SPSS. Descriptive statistics were utilized to examine group means, followed by inferential analyses, including ANOVA and Levene's test, to assess statistical significance and homogeneity of variance. This analytical approach supports the internal validity of the quantitative findings.

For qualitative data, participants' reflective journals were subjected to content analysis. To enhance the credibility of the qualitative results, the coding process was reviewed and finalized with the consensus of two independent mathematics education experts, thus contributing to inter-rater reliability. The consistency of qualitative themes with the quantitative findings further strengthens the construct validity of this study.

Rubric-based performance data were analyzed by calculating the frequencies and means for each dimension. These findings were used to interpret the general pedagogical performance of the teacher candidates in relation to sustainability-based practices. To enhance dependability and confirmability, all scoring procedures adhered to pre-established rubric criteria, and cross-checking among researchers was conducted.

In the final stage of this study, data triangulation was applied by comparing and integrating quantitative, qualitative, and rubric-based data. The convergence and complementarity of the different data sources were examined to ensure the overall trustworthiness of the findings. This methodological strategy allowed for a more comprehensive understanding of the effect of sustainability-focused microteaching practices on prospective mathematics teachers.

4. Results

4.1. Sustainability Belief Scale Results

In this study, the effect of a microteaching-based intervention on the sustainability beliefs of pre-service teachers studying in the primary school mathematics teaching program was examined. Within the scope of this study, the Sustainability Belief Scale was administered to participants both before and after the intervention. The participants were divided into experimental ($n = 22$) and control ($n = 23$) groups. The pre-test and post-test mean scores of the groups regarding their sustainability beliefs are given in Table 1:

Table 1. Intergroup comparisons and mean changes.

Research Group	Gender	N	Pre-Test Average (SD)	Post-Test Average (SD)
1 (Control)	1 (woman)	17	3.74 (0.91)	3.58 (0.49)
	2 (male)	6	4.36 (0.19)	3.23 (0.60)
	Toplam	23	3.90 (0.83)	3.49 (0.53)
2 (Experiment)	1 (woman)	14	3.75 (0.68)	3.76 (0.68)
	2 (male)	7	4.44 (0.39)	4.22 (0.58)
	Toplam	21	3.98 (0.68)	3.92 (0.67)
Grand Total	1 (woman)	31	3.75 (0.81)	3.67 (0.58)
	2 (male)	13	4.40 (0.30)	3.76 (0.77)
	Total	44	3.94 (0.75)	3.69 (0.63)

When the descriptive data are examined, it is observed that the pre-test and post-test means of the experimental group are quite close to each other, indicating that the sustainability belief level is maintained (pre-test: 3.98 and post-test: 3.92). In contrast, a decrease in the sustainability belief level is observed in the control group (pre-test: 3.90 and post-test: 3.49). A significant decrease in the post-test scores of the male participants in the control group ($4.36 \rightarrow 3.23$) is particularly striking. This shows that the intervention is effective in preserving and developing beliefs.

One-way analysis of variance (ANOVA) was performed to evaluate the difference between the post-test scores of the groups. Before the analysis, the homogeneity of variances was checked using the Levene test, and it was determined that the variances were equal (Levene's test, $p = 0.479$). This result supports the validity of the ANOVA test. The results obtained are given in Table 2.

Table 2. Post-test one-way analysis of variance (ANOVA) between groups.

Source	Sum of Squares	df	Mean Square	F	<i>p</i> (Sig.)	Partial Eta Squared
Corrected Model	1.974	1	1.974	5.408	0.025	0.114
Intercept	602.317	1	602.317	1649.853	<0.001	0.975
Research Group	1.974	1	1.974	5.408	0.025	0.114
Error	15.333	42	0.365			
Total	617.734	44				
Corrected Total	17.308	43				

According to the ANOVA results, the research group variable has a statistically significant effect on the dependent variable sustainability belief post-test scores, $F(1, 42) = 5.408$, $p = 0.025$. The effect size was calculated as $\eta^2 = 0.114$, which indicates a medium-level effect. Additionally, the model's explanatory power on the dependent variable was found to be 11.4% ($R^2 = 0.114$). This rate is a value considered significant in experimental education research.

The findings show that sustainability-based planning and teaching processes support and develop the sustainability beliefs of teacher candidates. This intervention, carried out through microteaching, contributed to reinforcing the sustainability-based thinking of the teacher candidates. In this regard, it can be stated that incorporating sustainable development goals into teacher training programs can enhance the awareness of teacher candidates regarding their environmental, social, and individual responsibilities.

4.2. Themes Emerging from Reflective Journals

The reflective diaries obtained from the prospective teachers were analyzed using the content analysis method, and as a result of the content analysis, five main themes were determined: pedagogical approach (PA), course flow (CF), difficulties experienced (DE), solution proposal (SP), and the prospective teacher's own performance (PTOP). Table 3 presents the codes and frequencies obtained from the groups in relation to these themes.

It is evident that all groups attempted to incorporate the theme of sustainability into various mathematics topics. While Group 1 and Group 5 focused on environmental issues directly related to daily life, such as water conservation and sustainable cities, Group 2 associated a more abstract concept, such as carbon footprint, with data analysis. This indicates that the prospective teachers employed various approaches in connecting the subject of sustainability to mathematics. In terms of pedagogy, it is noteworthy that methods such as "problem solving", "group work", "cooperative learning", "question-answer", and "presentation" stand out. This diversity indicates that the prospective teachers employed various teaching strategies and sought to develop their pedagogical skills.

Table 3. Themes and codes obtained from reflective journals of teacher candidate groups.

Group	Topics	PA	f	CF	f	DE	f	SP	f	PTOP	f
Group 1	Volumetric measurement—water saving	Group work	3	Presentation—question and answer—presentation—problem solving	1	The formulas were difficult for students to understand	2	Tangible material was used	3	I engaged the students in the lesson (positive)	2
		Problem solving	1	Reminder—Activity application—Presentation—Activity—Summary	3	Student comments are limited	3	More relatable to daily life	3	I could have explained it better (negative) It could be more related to daily life (negative)	1 1
		Cooperative learning	2							I could have known the subject better (negative)	1
										Interaction with the student was good (positive)	1
										I overcame my excitement (positive)	1
Group 2	Data analysis—carbon footprint									I could have given more examples from daily life (negative)	1
		Problem solving	2	Problem solving through daily life examples	3	Integration into sustainability	3	Writing your own problem	2	The flow of the lesson was good (positive)	2
		Group work	1	Presentation—Problem solving through group work	1	Lack of examples	1	Group work	1	Increasing problems from daily life (negative)	3
		Use of Technology	1					With peer learning	1	Using different resources (negative)	1
										Being able to use more technology (negative)	1
Group 3	First Order Equations—Recycling									Ability to add games (negative)	1
		Problem solving	5	Problem solving through daily life examples	5	Integration into sustainability	2	Writing your own problem	2	The flow of the lesson was good (positive)	2
		Cooperative learning	2	Group work	1	Students do not know about sustainability	2	More group work can be performed	1	I could have increased the use of technology (negative)	1
		Question- Answer	2	Subject explanation—Problem solving through daily life examples	3	Low student participation	2	Giving definitions and examples	1	Group work was good (positive)	1
		Presentation	1	Question and answer—presentation—problem solving	2			about sustainable	2	Association with daily life was good (positive)	1

Table 3. Cont.

Group	Topics	PA	f	CF	f	DE	f	SP	f	PTOP	f	
Group 4	Natural numbers and operations—Planting trees	Problem solving	3	Reminder—question and answer—problem writing with group work- Summary	4	Students do not know about sustainability	4	Adding an activity	1	The subject could have been explained in more detail (negative)	1	
										Keeping the student more active (negative)	1	
										Classroom management was strong (positive)	1	
										I could have prepared the material (negative)	1	
		Cooperative learning	2			Integration into sustainability	2	Problem solving	1	I asked good questions (positive)	1	
		Group work	1			Students had difficulty writing problems	1	Group work	1	Your lecture was good (positive)	1	
									Solving more examples	2	I could have solved more examples (negative)	1
Group 5	Area surveying—Sustainable city	Question—Answer	2	Exploration-based—Information-oriented	4	Students are becoming teacher candidates	1	Informing students by watching videos	1			
								Asking questions like a child	1	The flow of the lesson is good (positive)	3	
		Active participation	1				Students have incorrect or incomplete knowledge about sustainability.	3	Increasing the problems from daily life	3	I asked good questions (positive)	1
		Activity	2						Diversifying the problems from daily life	2		

The groups generally planned the flow of their lessons in a structured manner (e.g., “reminder–activity–presentation–problem solving–summary”). Groups such as Groups 1 and 3 varied the flow of their lessons by blending different teaching methods. Group 5 used a combination of exploratory and informative approaches, indicating that the prospective teachers tended to blend both constructivist and explanatory approaches.

One of the most frequently encountered difficulties was that students lacked sufficient knowledge about sustainability (Groups 3, 4, and 5). This situation illustrates that prospective teachers struggle to convey the abstract and new concept of sustainability to students. In addition, classic teaching difficulties, such as “difficulty in understanding formulas,” “limited student comments,” and “low student participation,” were also emphasized. Figure 2 shows examples of difficulties experienced by prospective teachers in their reflective journals.

<i>“Students had inaccurate and incomplete information about sustainability. This created difficulties.” (EPT20, Group5)</i>	<i>“They lacked knowledge about sustainability and did not actively participate in question resolution..” (EPT11, Group3)</i>
<i>“Abstract formulas were difficult for students to understand.” (EPT1, Group1)</i>	<i>“Interaction with students was a bit weak. Few students expressed their opinions.” (EPT10, Group3)</i>

Figure 2. Examples of difficulties experienced by prospective teachers in their reflective journals.

The candidates suggested solutions such as using more concrete materials, making connections with daily life, and integrating games and technology. It is noteworthy that Group 2 suggested using more modern pedagogical tools such as “using technology”, “peer learning”, and “gamification”. Groups 4 and 5 made suggestions that combined classical and modern approaches, such as “solving more examples” and “showing videos.” The teacher candidates demonstrated their self-regulation skills with solution suggestions such as using concrete materials (Group 1), diversifying activities and examples (Groups 3, 4, and 5), and turning to technology and video (Groups 2 and 4). These suggestions indicate that the candidates can critically examine their own teaching processes and are open to improvement.

Most of the teacher candidates evaluated their own performance critically. In Group 1, candidates made self-criticisms such as “I could have known the subject better”, “I could have explained it better”, while in Groups 3 and 5, there were also positive reflections such as “classroom management is strong”, “the flow of the lesson was good”, and “group work was good”. This indicates that the candidates have begun to develop their reflective thinking skills and can critically evaluate their teaching processes.

Reflective diaries reveal that pre-service teachers increased their pedagogical and personal awareness in sustainability-based mathematics teaching. The candidates explored various teaching strategies throughout the processes of lesson planning, implementation, and evaluation, allowing them to identify both their strengths and areas in need of development. Although integrating sustainability presented certain challenges, their ability to generate solutions and engage in self-reflection indicates that the process was beneficial for their professional development.

4.3. Rubric Evaluation Results

This section presents the findings derived from the rubrics developed to evaluate the sustainability-based lesson plans and microteaching practices of the prospective teachers.

The evaluation process was based on various criteria, including the alignment of the teaching content with sustainability, the clarity of learning objectives, student participation and interaction, the applicability of pedagogical methods, the use of instructional materials, assessment strategies, and overall teaching competence. The quantitative data obtained from the rubrics enabled a comparative analysis of teaching competencies between the groups and offered a comprehensive assessment of the extent to which prospective teachers were able to integrate sustainability principles into their instructional practices. The prospective teachers' lesson plans and microteaching practices were scored using the 4-point Likert-type rubrics previously prepared by the researcher (The scoring criteria are detailed in Appendices A and B). Table 4 shows the scores of teacher candidate groups based on lesson plan rubrics.

Table 4. Scores of teacher candidate groups based on lesson plan rubrics.

Criterion	Group 1	Group 2	Group 3	Group 4	Group 5	Total	$\bar{x}$
1. Course Content and Suitability of Objectives	4	3	3	4	4	18	3.6
2. Suitability of Activities and Events	4	2	3	4	4	17	3.4
3. Mathematical Approach and Applications	4	3	4	4	4	19	3.8
4. Interest and Participation	4	2	3	4	4	17	3.4
5. Resources and Tools	4	2	2	3	4	15	3.0
6. Evaluation and Feedback	3	2	3	3	3	14	2.8
7. Achieving Learning Objectives	4	3	3	4	4	18	3.6
8. Social and Environmental Awareness	4	2	4	4	4	18	3.6
Total	31	19	25	30	31	-	-
$\bar{x}$	3.87	2.37	3.12	3.75	3.87	-	-

When the groups are considered in general, it is evident that Groups 1, 4, and 5 have prepared very good-level lesson plans according to the rubric. In these plans, especially in terms of the suitability of the objectives, mathematical integrity, participation, and sustainability awareness stand out with high scores. Group 3 has prepared a generally good lesson plan, and despite some deficiencies, it has created a strong lesson plan overall. Group 2 remained below average, and the lesson plans need to be developed, especially in terms of attractiveness, resource utilization, and evaluation. Group 1 presented a strong STEM-based lesson plan by covering the topic of volume in the context of rainwater collection. The 5E model was used effectively, and engineering thinking skills were supported.

Figure 3 shows examples of activities in the lesson plans of Groups. Group 2 aimed to analyze environmental data; however, the depth of the activity was limited. Group 3 focused on modeling and awareness development by associating linear equations with environmental problems. Group 4 established a simple yet meaningful relationship between

sustainability and mathematics. Group 5 established a strong interdisciplinary structure by combining area calculation with the theme of a sustainable city and supported it with digital tools. The section in which the groups received the lowest scores in their lesson plans was Evaluation and Feedback (2.8).

Where is Water Used?

"Do you think we could use rainwater to replace some of the water we use in our homes?"

"If we were to build a water tank for this purpose, how could we calculate how many liters of water it could hold?"

Let's design a tank together.



Question: Recycling and Waste Amount

Data Table:

Daily Waste Amount (kg)	Recycled Material (kg)
1	0.3
2	0.6
3	0.9



The relationship between the amount of daily waste per person in a city and the amount of recycled materials is examined.

Task: Using this data, students create a linear equation and draw its graph.

Group 1, Volume topic, water saving activity example

Group 3, Linear equations topic, Recycling

Figure 3. Examples of activities in the lesson plans of Group 1 and Group 3.

Among the prepared lesson plans, especially those based on volume, area, and natural numbers, establish meaningful and creative connections between sustainability and mathematical skills. The fact that the activities are appropriate for the age level, related to daily life, problem-centered, and value-focused has made these plans suitable for the constructivist and contemporary education approach. Inadequate use of visual-digital resources and limited definition of evaluation processes in some plans were the missing elements. Table 5 includes scores of teacher candidates from rubrics regarding microteaching practices.

The findings obtained within the scope of the microteaching practices carried out reveal that the pedagogical competencies of the prospective teachers towards sustainability-based mathematics teaching have generally developed at a positive level. Especially the high scores of Groups 1, 4, and 5, which indicate a "Very Good" level of performance, demonstrate that these groups have adopted a student-centered, participatory, and strategic teaching approach by integrating the concept of sustainability with mathematical content. While high success was observed in areas such as clarity of learning objectives, diversity of teaching strategies, and classroom management, it is understood that the evaluation and feedback processes were insufficient in all groups and that the use of sustainability-based materials should be planned more systematically. The generally below-average performance of Group 2, in particular, shows that more structured support and guidance are needed in designing and implementing sustainability-based teaching.

Table 5. Scores of teacher candidates from rubrics regarding microteaching practices.

Evaluation Criteria	Group 1	Group 2	Group 3	Group 4	Group 5	Total	$\bar{x}$
1. Sustainability Linkage of Teaching Content	4	3	3	4	4	18	3.6
2. Student Participation and Interaction	4	2	3	4	4	17	3.4
3. Clarity of Learning Objectives	4	3	3	4	4	18	3.6
4. Pedagogical Approach and Teaching Strategies	4	3	4	4	4	19	3.8
5. Use of Resources and Materials	4	2	2	3	4	15	3.0
6. Evaluation and Feedback	3	2	3	3	3	14	2.8
7. Classroom Management and Response to Student Needs	4	3	3	4	4	18	3.6
Total	27	18	21	26	27	-	-
$\bar{x}$	3.85	2.57	3.00	3.71	3.85	-	-

In general, microteaching practices significantly improved the pedagogical competencies of pre-service teachers in teaching sustainability-based mathematics. However, performance differences were observed between the groups; while some groups exhibited strong and effective teaching approaches, other groups were found to have deficiencies, especially in evaluation processes and material use. A similar trend was observed between the lesson plans and microteaching practice scores of the pre-service teacher groups. At the same time, the elements that the group members expressed in their reflective journals regarding microteaching practices were parallel to the scores they received from the lesson plan rubric and the microteaching rubric.

5. Discussion

This study examined the development of primary school mathematics teacher candidates' beliefs towards sustainability-based microteaching practices through various data collection and analysis methods. While the change in the candidates' sustainability beliefs was evaluated with the pre-test-post-test design, reflective journals provided an opportunity to understand the candidates' experiences and pedagogical awareness in depth during the implementation process. In addition, the pedagogical competencies of the candidates were quantitatively assessed by scoring their lesson plans and micro-teaching performances using rubrics. In the discussion section, these findings will be evaluated in light of the relevant literature, and the contributions and possible limitations of this study to the field of education will be emphasized.

5.1. Development of Sustainability Beliefs in Pre-Service Teachers

The quantitative findings obtained regarding the Sustainability Belief Scale show that sustainability-based planning and teaching processes support and develop the sustainabil-

ity beliefs of pre-service teachers. This intervention, through micro-teaching, contributed to the reinforcement of pre-service teachers' sustainability-based ways of thinking. Numerous studies suggest that sustainability-based planning and teaching processes support and foster the sustainability beliefs of pre-service teachers. For example, Tilbury (2018) [54] emphasized that sustainability-oriented educational practices enhance teachers' perceptions in this area and contribute to the development of their pedagogical competence. Similarly, Leicht, Heiss and Byun (2018) [55] has shown that sustainability-based pedagogical approaches in teacher training programs positively affect candidates' understanding of sustainability. Hawkes (2019) [56] stated that microteaching and applied teacher education processes have a transformative effect on the sustainability beliefs and attitudes of prospective teachers. Rieckmann (2017) [57] has also revealed that learning processes play a critical role in the development of attitudes and beliefs of prospective teachers by creating a transformation in terms of sustainability. In parallel, Che and Zhang (2021) [58] highlighted that integrating Education for Sustainable Development (ESD) into pre-service mathematics teacher education fosters candidates' critical thinking and strengthens their capacity to link mathematical content with sustainability issues. Similarly, Olsson, Gericke, and Rundgren (2016) [59] found that structured ESD implementation in schools significantly improves students' sustainability consciousness, which underscores the importance of such approaches in teacher education contexts as well. These studies demonstrate that sustainability-based education processes foster the development of sustainability awareness at the cognitive level, as well as enhance the pedagogical competencies of prospective teachers.

5.2. *The Role of Reflective Diaries and Lesson Plan Content*

Reflective diaries reveal that pre-service teachers increased their pedagogical and personal awareness in sustainability-based mathematics teaching. Candidates employed various teaching strategies in lesson planning, implementation, and evaluation processes, identifying their strengths and areas for development. Although the integration of sustainability presents certain challenges, the candidates' ability to generate solutions and engage in self-reflection indicates that the process was beneficial for their professional development. Loughran (2019) [60] emphasizes that reflective journals enrich prospective teachers' thinking about the teaching process and deepen their professional growth. Similarly, Korthagen and Vasalos (2018) [61] stated that reflective practices enhance individuals' internal awareness, enabling them to make more informed instructional decisions on value-based issues such as sustainability. Hart and King (2020) [62] in their research on sustainability education, revealed that reflective diaries developed both the sustainability knowledge and pedagogical approaches of prospective teachers in a holistic manner. In addition, Vossoughi and Bevan (2019) [63] in their studies in the STEM field, state that reflective practices increase the pedagogical flexibility and sensitivity of pre-service teachers in interdisciplinary themes such as sustainability. From a broader teacher education perspective, Nolet (2009) [64] argues that cultivating sustainability literacy in teacher candidates requires reflective, value-based instructional practices—such as the use of reflective diaries—which integrate ethical considerations with subject-specific pedagogy. These findings show that reflective journals support the development of a multidimensional awareness in sustainability-based mathematics teaching.

Among the prepared lesson plans, especially those based on volume, area, and natural numbers, establish meaningful and creative connections between sustainability and mathematical skills. Similarly, Jaber (2020) [65] indicates that teacher candidates enhanced both students' environmental awareness and mathematical problem-solving skills by integrating sustainability themes such as recycling, water conservation, and energy use with topics like area and volume through project-based approaches. In the same vein, Öhman

and Östman (2021) [66] states that content areas such as natural numbers, measurement, and ratios—when structured within the context of sustainability—contribute to students' conceptual understanding. Likewise, Papenfuss and others (2019) [67] has shown that associating mathematical concepts such as volume, area, and number systems with sustainable life practices fosters creativity in teacher candidates and strengthens their ability to relate mathematics instruction to real-life contexts. Che and Zhang (2021) [58] similarly observed that embedding sustainability contexts into mathematics topics such as measurement and number systems not only increases candidates' creativity but also improves their ability to design real-life connected learning environments. These studies show that teacher candidates develop both their pedagogical creativity and design more meaningful learning environments for students by establishing strong connections with sustainability, especially in subjects such as measurement, area, and number systems. The fact that the activities are appropriate for the age level, related to daily life, problem-centered, and value-oriented has made these plans compatible with the constructivist and contemporary education approaches. Inadequate use of visual-digital resources and limited definition of evaluation processes in some plans were the missing elements.

5.3. Microteaching Practices and Holistic Competence Development

Microteaching practices enable prospective teachers to significantly develop their pedagogical competencies in teaching mathematics based on sustainability. Indeed, research has shown that such practices provide significant gains in teaching design, classroom management, and conceptual integrity [35,68]. However, it is emphasized that significant performance differences were observed between the groups in the microteaching process, and these differences emerged especially in the structuring of the evaluation processes and the use of materials [18,69]. While some groups developed effective and creative teaching strategies, other groups showed inadequacy in integrating sustainability concepts into classroom practices and in structuring assessment and evaluation tools in a meaningful way. While these findings highlight the importance of microteaching practices in developing sustainability-based teaching competencies among prospective teachers, they also underscore the need for individual or group-based supportive interventions. Olsson, Gericke, and Rundgren (2016) [59] note that structured, practice-based sustainability education is essential for fostering consistent performance across teaching tasks, as it builds both conceptual knowledge and applied competence—principles directly relevant to microteaching contexts.

Current research supports the idea that prospective teachers demonstrate consistent and holistic development across the processes of lesson planning, microteaching implementation, and reflective thinking. Borko, Jacobs and Koellner (2019) [70] revealed that there is a significant relationship between the quality of teacher candidates' lesson plans and their microteaching performance and that these two processes generally exhibit similar pedagogical tendencies. Similarly, Rodgers (2020) [71] indicates that the reflective diaries closely align with the strengths and weaknesses of prospective teachers during the planning and implementation phases, emphasizing that the themes expressed in their reflections are consistent with their rubric scores. Lannin, Webb, Chval and Arbaugh (2021) [72] notes that the thematic coherence demonstrated by prospective teachers in sustainability-based mathematics lesson plans is directly reflected in both their classroom performance and reflective thinking. The contemporary perspective offered by [73] further supports these findings, suggesting that pedagogical alignment across planning, implementation, and reflection processes plays a critical role in the professional development of pre-service teachers. In this context, the consistency observed among lesson plans, microteaching practices, and reflective journals suggests that prospective teachers are developing their

sustainability-oriented teaching competencies in a holistic and integrated manner. Nolet (2009) [64] reinforces this by asserting that teacher preparation programs should ensure such holistic integration across instructional planning, enactment, and reflection if the goal is to produce sustainability-literate educators.

6. Conclusions

This study revealed that primary school mathematics teacher candidates demonstrated significant development in their beliefs and awareness regarding sustainability through sustainability-based microteaching practices. The results obtained are presented in the context of the research questions, and finally, implications and recommendations are stated.

6.1. The Effect of Sustainability-Focused Microteaching Practices on Pre-Service Teachers' Beliefs About Sustainability

The quantitative findings from the pre-test and post-test comparisons indicated that engaging in sustainability-oriented planning and teaching processes effectively strengthened the candidates' beliefs about sustainability. These beliefs were not only enhanced but also visibly reflected in their teaching practices. The microteaching intervention played a transformative role in shifting the teacher candidates' perspectives, empowering them to integrate sustainability themes into mathematical content. This demonstrates the potential of experiential teaching models in fostering sustainability literacy within teacher education programs.

6.2. Reflections in Journals: Pre-Service Teachers' Perceptions of Sustainability and Teaching Processes

Qualitative data derived from the reflective journals of pre-service teachers provided valuable insights into their perceptions of sustainability and their evolving pedagogical thinking. The experiences and reflections shared in the journals were largely aligned with the performance scores they received in lesson plan and microteaching rubric evaluations. This alignment suggests a strong internal consistency between the planning, implementation, and reflection stages of their teaching. Many teacher candidates articulated a growing understanding of the complex, multidimensional nature of sustainability and acknowledged both the opportunities and challenges of incorporating sustainability themes into their teaching. These reflective practices thus served not only as documentation but also as a tool for deepened conceptual engagement.

6.3. Pedagogical Elements Observed in Sustainability-Based Mathematics Lesson Plans

An analysis of the lesson plans developed by pre-service teachers revealed that they effectively integrated core mathematical concepts—such as volume, area, and natural numbers—with sustainability themes. These plans often addressed environmental, economic, and social dimensions, resulting in rich, interdisciplinary instructional designs. A notable feature across most plans was the adoption of constructivist teaching approaches: activities were age-appropriate, rooted in real-life contexts, and designed around problem-solving. These pedagogical elements highlight the candidates' growing competence in designing sustainability-integrated mathematics instruction, showing creativity and a commitment to meaningful, contextual learning.

6.4. Effectiveness of Assessment Rubrics in Capturing Sustainability Integration

Findings related to the assessment rubrics used during the microteaching practices indicated significant performance differences among groups. While some groups demonstrated strong integration of sustainability into their mathematics teaching through well-structured and impactful pedagogical strategies, others struggled—particularly in areas

like evaluation planning and the use of digital or visual materials. The rubric results were effective in capturing these variations, as they provided a multidimensional evaluation of planning and instructional implementation. These findings suggest that both individual and group-level factors influence the development of sustainability-based teaching competencies, reinforcing the importance of differentiated support and feedback mechanisms in teacher education programs.

6.5. Implications and Recommendations

However, it is a striking finding that there are significant performance differences between the groups in the context of microteaching practices. While some groups successfully integrated the sustainability theme into mathematics teaching by exhibiting strong and effective teaching approaches, it was determined that other groups showed deficiencies, especially in structuring evaluation processes and using digital and visual materials. This situation highlights that both individual and group-based variables are effective in developing sustainability-based teaching competencies and that teacher candidates should be supported at various levels.

In this respect, developing targeted pedagogical support strategies that consider the variability among candidates may significantly enhance the overall quality and consistency of sustainability-based instructional practices.

In general, this study demonstrates that sustainability-based mathematics teaching yields multidimensional benefits in terms of the professional development of pre-service teachers, with a dynamic interaction between beliefs, awareness, and pedagogical skills. The integrity that pre-service teachers establish between the lesson planning, implementation, and reflection processes reveals that their capacity to integrate sustainability literacy into teaching processes has improved, and it shows that such holistic teaching experiences should be systematically integrated into teacher education programs.

Future research may explore the systematic integration of sustainability-based teaching approaches into teacher education programs, along with the development of micro-teaching practices, reflective thinking, and interdisciplinary planning skills. Investigating the impact of linking concrete mathematical concepts to sustainability on creative thinking and problem-solving, designing multidimensional assessment tools, and examining pedagogical performance differences in relation to support strategies may also offer valuable insights. In this context, planning longitudinal studies supported by follow-up measurements at different time intervals would make a valuable contribution to better evaluating the effects of sustainability-based instruction on pre-service teachers. Additionally, incorporating reflective journal analyses into professional development frameworks and exploring the long-term effects of sustainability-focused instruction can be addressed across diverse educational contexts.

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Abbreviations

The following abbreviations are used in this manuscript:

STEM	Science, Technology, Engineering, and Mathematics
KMK	Standing Conference of Ministers of Education and Culture journals
BMZ	Federal Ministry for Economic Cooperation and Development
PCK	pedagogical content knowledge
EPT	teacher candidate in the experimental group
CPT	teacher candidates in the control group
PA	pedagogical approach
CF	course flow
DE	difficulties experienced
SP	solution proposal
PTOP	the prospective teacher's own performance

Appendix A. Sustainability-Based Mathematics Lesson Plan Assessment Rubric

Table A1. Sustainability-Based Mathematics Lesson Plan Assessment Rubric.

Criteria	Excellent (4 Points)	Good (3 Points)	Medium (2 Points)	Not Developed (1 Point)
Course Content and Suitability of Objectives	Mathematical concepts related to sustainability are covered in depth and clearly targeted. The objectives provide students with skills in the context of environmental, economic, and social sustainability.	The sustainability theme is associated with mathematical concepts, but the objectives are not completely clear.	The sustainability theme is covered in a limited way, with some goals being unclear.	The sustainability theme is poorly covered, and the mathematical objectives are not clear.
Applications and Activities	Activities and events enable students to think deeply about sustainability issues and develop their creative and problem-solving skills.	Activities are meaningful in the context of sustainability, but some could be more effective in achieving this goal. They support the mathematical thinking process well.	Activities provide a general overview of the sustainability theme but could have been more creative or interesting.	Activities are insufficient or have a weak connection to the sustainability theme. Mathematical skills are not developed.
Mathematical Approach and Applications	Mathematical concepts are skillfully combined with the sustainability theme, allowing students to learn in depth by working on real-world problems.	Mathematical concepts are well integrated, but some sections could have been practiced more thoroughly.	Mathematical concepts are generally treated in a linear manner, with little connection made to sustainability.	The connection between mathematical concepts and sustainability is weak, and there is no practical approach.
Interest and Participation	The course content, which attracts students' attention and encourages active participation, is supported by sustainability-themed problems and discussions.	Some activities are interesting for students, but participation could have been encouraged more.	Some parts of the course do not interest students, and participation is limited.	The entire course is boring, and participation is low; students do not actively engage.

Table A1. *Cont.*

Criteria	Excellent (4 Points)	Good (3 Points)	Medium (2 Points)	Not Developed (1 Point)
Resources and Tools	Resources and tools (visuals, models, technology, etc.) are used effectively to support mathematical problems with sustainability themes.	The resources are well-selected, but some tools could have been utilized more efficiently.	Resources and tools are used limitedly, more variety is needed to support sustainability and mathematical context.	Resources and tools are insufficient; they do not contribute to the course content.
Assessment and Feedback	Students' learning processes are continuously evaluated and feedback is provided with sustainability-themed projects.	The evaluation and feedback process was based on specific criteria, but some students may require additional explanation.	Evaluation is provided, but feedback is generally superficial.	Assessment and feedback are absent or very limited. Student progress could not be monitored.
Achieving Learning Objectives	By the end of the course, students have developed mathematical skills related to sustainability and can apply them to real-world contexts.	Students demonstrated an understanding of basic sustainability and mathematical connections by the end of the lesson.	Although students understand some basic concepts, they do not have a deeper understanding.	Students did not achieve most of the targeted learning outcomes.
Social and Environmental Awareness	The course plan enables students to develop social and environmental awareness about sustainability.	The lesson plan provides students with information on environmental and social sustainability.	The lesson plan provides students with limited environmental and social awareness.	The course plan does not provide students with sufficient social and environmental awareness in terms of sustainability.

Appendix B. Microteaching Evaluation Rubric: Sustainable-Based Mathematics Education

Table A2. Microteaching Evaluation Rubric: Sustainable-Based Mathematics Education.

Evaluation Criteria		Levels of Success	Point			
			4	3	2	1
1.	Sustainability Linkage of Teaching Content	4: Teaching explicitly links mathematical concepts and processes to sustainability. Strong links are established among the environmental, social, and economic dimensions. 3: Teaching is linked to sustainability, but the links are not strong enough. 2: The concept of sustainability is only superficially included in teaching. 1: Links to sustainability are not clearly present.				
2.	Student Participation and Interaction	4: Students actively participate, and meaningful interactions occur with the guidance of the teacher candidate. Suggestions are made to solve environmental or social problems. 3: Students participate, but the depth and meaningfulness of the interactions are limited. 2: Student participation and interaction are limited, usually consisting of repeating what the teacher says. 1: Students do not participate.				
3.	Clarity of Learning Objectives	4: Learning objectives are clear, explicit, and measurable. Objectives include sustainability-themed mathematical skills. 3: Objectives are specific, but some may not be clear enough in the context of sustainability. 2: Learning objectives are vague and do not make direct connections to sustainability. 1: Learning objectives are vague and unrelated to sustainability.				
4.	Pedagogical Approach and Teaching Strategies	4: Teaching strategies emphasize sustainability while developing students' mathematical thinking skills. Variety is added to the lesson by using various teaching methods. 3: Teaching strategies develop mathematical skills, but sustainability elements are limited. 2: Teaching strategies are based on a single method and sustainability is emphasized very little. 1: Teaching strategies are ineffective and sustainability is not used at all.				

Table A2. Cont.

Evaluation Criteria		Levels of Success	Point			
			4	3	2	1
5.	Use of Resources and Materials	4: Course materials provide examples of sustainability and environmentally friendly resources are used. Students are encouraged to think environmentally sensitively. 3: Materials are suitable for teaching, but materials directly related to sustainability are few. 2: Course materials are limited and do not focus on sustainability. 1: Resources are insufficient and the concept of sustainability is ignored.				
6.	Evaluation and Feedback	4: Feedback from students improves their understanding of sustainability as well as mathematical processes. Assessment processes are clear and diverse. 3: Feedback is limited to mathematical processes, and there is little emphasis on sustainability. 2: The assessment process is one-way, and there is limited feedback on sustainability. 1: The assessment process is absent or creates misunderstandings.				
7.	Classroom Management and Response to Student Needs	4: Classroom management is effective, and solutions have been developed to address the diverse learning needs of students. Everyone is included in the lesson with sustainability-themed examples. 3: Classroom management is generally effective, but the needs of some students may be ignored. 2: Classroom management is weak and does not focus enough on student needs. 1: Classroom management is inadequate, and the diverse needs of students are not being addressed.				

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