



ENHANCING MATHEMATICAL FLUENCY: IMPACT OF THE FLIPPED LEARNING MODEL ON MIDDLE SCHOOL STUDENTS' ACADEMIC ACHIEVEMENT AND DOMAIN-SPECIFIC LANGUAGE USE

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Abstract: This study examines the effects of the flipped learning model on middle school students' academic achievement and domain-specific language use. A pretest-posttest control group quasi-experimental design was employed, involving 98 students from a middle school in Istanbul during the 2021-2022 academic year. Over five weeks, the experimental group received flipped learning instruction, while the control group was taught using traditional methods. Academic achievement and language proficiency were assessed using the Decimal Notation Achievement Test and the Domain Language Scale. The results revealed that the flipped learning model significantly improved academic achievement and enhanced students' use of mathematical symbols, verbal expression, and model representation. These findings demonstrate the model's effectiveness in developing both academic performance and domain-specific language skills.

Key words: flipped learning model, mathematics domain-specific language, academic achievement, decimal notation, mathematics education

1. Introduction

The COVID-19 pandemic has emphasized the need for student-centered, engaging, and developmentally appropriate learning environments for middle school students. The shift to remote learning showcased technology's ability to provide accessible education beyond traditional constraints (Filiz & Kurt, 2015). This has reshaped educators' perceptions, highlighting technology's role in enhancing educational quality (Chun & Yunus, 2023; Thapaliya et al., 2023). In this context, flipped learning has gained attention as an effective pedagogical approach. Research shows that integrating technology into mathematics education improves conceptual understanding and promotes mathematical language use (Νικολοπούλου, 2020; Kramarenko, 2023; Mohamed et al., 2020; Engelbrecht et al., 2020). Aligned with the Characteristics of Successful Middle Schools, flipped learning fosters active learning, equitable access, and educator collaboration. This study explores how flipped learning enhances middle school students' academic achievement and mathematical language proficiency.

2. Theoretical Framework

2.1. Flipped Learning Model and Its Alignment with Middle School Best Practices

Flipped learning, a blended learning approach, combines face-to-face and online modalities to support continuous learning inside and outside the classroom. It delivers instructional content, often via online videos, outside class to enable interactive and collaborative in-class activities (Lo & Hew, 2017). Students prepare with pre-class materials and reinforce learning through post-class activities (Abeysekara & Dawson, 2015). Çevikbaş (2018) highlights the alignment of flipped learning with

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Bloom's cognitive domain taxonomy, illustrating its impact on cognitive engagement, as depicted in Figure 1.

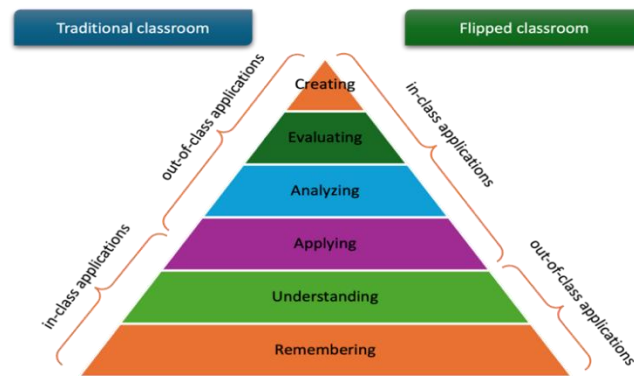


Figure 1. Reflection of Flipped Learning on Bloom's Cognitive Domain Taxonomy (Çevikbaş, 2018)

The flipped classroom model offers significant benefits, particularly in mathematics education, by improving student engagement and conceptual understanding (Brown et al., 2022). It fosters critical thinking, independent learning, and satisfaction when implemented effectively (Pang, 2022). Ahmed & Indurkha (2020) highlight its ability to reduce learning costs while enhancing application skills and peer-based learning. Nouri (2016) found that flipped learning, as a flexible and student-centered approach, positively impacts motivation, participation, and learning outcomes. A review of the literature highlights numerous studies using the flipped learning model in mathematics instruction, as outlined in Table 1.

Table 1. Studies on Flipped Learning in Mathematics Teaching

Subject	Studies
• Examining the opinions of students, teachers, parents and academicians regarding the model	• Akbulut, 2019; Çakıroğlu, 2020; Erensayın, 2019
• Examining the effect of the model on academic success	• Akdeniz, 2019; Arslan, 2021; Aydın, 2020; Bulut, 2019; Camcı, 2022; Doğru, 2022; Flick, 2019; Gürer, 2023; Wiley, 2015
• Examining the effect of the model on affective properties towards mathematics	• Ağırman, 2023; Arslan, 2021; Çevikbaş, 2018; Özdemir, 2016; Wiley, 2015
• Meta-analysis or literature review studies regarding the model	• Çiftçi ve diğ., 2022; Doğan, 2022; Fernandez-Martin, 2020; Güler ve diğ., 2023; Yıldırım Yakar, 2021

2.2. Mathematics Domain Language

Mathematical domain language is universally used by mathematicians and students to communicate ideas. Gray (2004) describes it as a structured system of words, symbols, graphics, and rules. Domain language is a crucial aspect of mathematics education and significantly influences students' learning experiences. Riccomini et al. (2015) highlighted the importance of teaching mathematical vocabulary for students' conceptual learning. In this context, language not only facilitates the expression of mathematical ideas but also shapes how students construct mathematical meanings, demonstrating the intricate connection between language and mathematical understanding.

3. Importance of The Study

This study is significant as it addresses a gap in the literature by exploring the impact of the flipped learning model on mathematical content language, specifically in the teaching of decimal notation—a topic with limited prior research (Flick, 2019; Lee et al., 2011; Toh et al., 2017; Wiley, 2015). By

incorporating symbolic, verbal, and model aspects of domain language into lessons, the study aims to provide insights into how the flipped classroom model can enhance students' academic achievement and their ability to effectively use mathematical domain language. The findings are expected to contribute to the theoretical understanding of flipped learning in mathematics education and offer practical guidance for educators seeking to improve students' conceptual understanding and language proficiency in mathematics. Therefore, the purpose of this study is to examine the impact of the flipped learning model on middle school students' academic achievement and domain language use in the subject of "Decimal Notations". The sub-problems of the study are as follows:

HQ₁: Is there a significant difference in academic achievement between students taught "Decimal Notations" using the flipped learning model and those taught with traditional methods?

HQ₂: Is there a significant difference in the use of mathematical symbols between students taught "Decimal Notations" using the flipped learning model and those taught with traditional methods?

HQ₃: Is there a significant difference in verbal expression between students taught "Decimal Notations" using the flipped learning model and those taught with traditional methods?

HQ₄: Is there a significant difference in model-based representations between students taught "Decimal Notations" using the flipped learning model and those taught with traditional methods?

Based on the research questions, the following directional hypotheses were tested (H₁–H₄):

H₁: Students in the flipped learning model will demonstrate **higher post-test academic achievement** in decimal notation than students receiving traditional teaching.

H₂: Students in the flipped learning model will demonstrate **higher post-test mathematical symbol usage** in decimal notation than students receiving traditional teaching.

H₃: Students in the flipped learning model will demonstrate **higher post-test verbal expression** in decimal notation than students receiving traditional teaching.

H₄: Students in the flipped learning model will demonstrate **higher post-test ability to represent decimal notation with models** than students receiving traditional teaching.

4. Methodology

4.1. Research Design

This study employed a quasi-experimental pretest-posttest control group design, as outlined in Table 2.

Table 2. *Experimental Design of The Research*

Group	Pre-test	Experimental Process	Post-test
• Experimental	• Achievement test • Domain Language Scale	• Flipped Learning Model	• Achievement test • Domain Language Scale
• Control	• Achievement test • Domain Language Scale	• Traditional Teaching	• Achievement test • Domain Language Scale

4.2. Study Group

The study group included 98 fifth-grade students from a public school in Istanbul's Kâğıthane district during the 2021-2022 academic year, with 49 students in each of the experimental and control groups.

The school was chosen as it is the researcher's workplace. The experimental and control groups were selected using criterion sampling, a purposive method, based on two criterias:

- 1) Having at least one technological device, such as a phone, computer, tablet, or television with video playback capabilities, at home
- 2) Having an internet connection at home

Students without the necessary resources were placed in the control group, as the flipped learning model requires students to watch instructional videos at home. Selection criteria ensured the experimental group could meet these requirements. Participation was voluntary, and all students were informed about the study's purpose. The demographic details of the study group are shown in Table 3.

Only students who completed both the pretest and posttest were included in the study. Those who participated in only one of the tests were excluded, leading to differences in the number of students in the study group.

Table 3. Demographic Structure of The Study Group

Test	Gender	Experimenal Group	Control Group
Achievement Test	Female	22	22
	Male	27	27
	<i>Total</i>	49	49
Domain Language Scale	Female	21	20
	Male	24	25
	<i>Total</i>	45	45

4.3. Data Collection Tools

This study used two primary data collection instruments: the "Decimal Notation Achievement Test" and the "Domain Language Scale" developed by the researcher.

4.3.1. Decimal Notation Achievement Test. The "Decimal Notation Achievement Test," designed by Karataş (2019), was developed to assess the competencies below:

- Determines that when a whole is divided into 10, 100 and 1000 equal parts, the units of the resulting fraction can be expressed in decimal notation;
- Expresses a fraction with a denominator of 10, 100 or 1000 in decimal notation;
- Understands the relationship between the digits in decimal notation and the value of the digit;
- Writes and reads the decimal representation of fractions that can be simplified or expanded with a denominator of 10, 100 or 1000;
- Shows and sorts the numbers given in decimal notation on the number line;
- Performs addition and subtraction operations with numbers given in decimal notation.

A pool of 60 multiple-choice questions was initially created, with 10 for each learning outcome, and validated through expert review. The test was piloted with 120 sixth-grade students, scoring 1 point for correct answers and 0 for incorrect ones. Based on the pilot, the test was refined to 20 open-ended questions, considering item difficulty, discrimination, and consistency. The final test scores range from 0 to 20, with a Kuder-Richardson (KR) reliability coefficient of 0.80, indicating high reliability.

4.3.2. Domain Language Scale. The "Domain Language Scale," developed by the researcher, includes 12 open-ended questions to assess fifth-grade students' use of domain language in "Decimal Representations". It evaluates three dimensions: modeling, use of mathematical symbols, and verbal expression. Unlike multiple-choice questions, open-ended questions provide a deeper understanding of students' deficiencies and development by allowing them to express their thoughts in their own words. The development process of the scale was carried out in five stages: 1) Identification of objectives 2) Preparation of draft scale items 3) Examination of construct validity 4) Piloting the draft scale 5) Creation of the final scale form.

To develop the scale, questions were designed to align with relevant learning outcomes and be suitable for fifth graders. Resources such as the Turkish Ministry of National Education 5th grade mathematics textbook, supplementary materials, and achievement tests were reviewed, resulting in 22 draft open-ended questions. Feedback on the questions' suitability, clarity, and use of mathematical language was gathered from six mathematics teachers and five expert lecturers using an expert opinion form. Experts rated each question as "Appropriate," "Inappropriate," or "Needs Improvement" and provided suggestions for improvement when needed.

Based on expert feedback, unsuitable questions were removed, and others were revised to address deficiencies. The draft scale was piloted with 25 sixth-grade students from a public school in Istanbul. Students were informed about the research, encouraged to share feedback, and given 50 minutes to complete the questions. Based on their responses, unclear or ineffective questions were removed or simplified. The finalized "Domain Language Scale" includes 12 open-ended questions: 4 on modeling, 33 on mathematical symbols, and 29 on verbal expression.

The Domain Language Scale was evaluated in three dimensions—modeling, mathematical symbols, and verbal expression—using a researcher-developed rubric based on existing literature. Responses were scored as follows: "0" for blank/irrelevant answers, "1" for incorrect/insufficient answers, "2" for partially correct answers, and "3" for fully correct answers. The number of items and scores for each dimension are shown in Table 4.

Table 4. Number of items and scoring of the scale according to the questions

Outcomes	Questions	Mathematical Symbol Usage	Verbal Expression	Representation with Model
1-2	1	5 items (15 pts)	2 items (6 pts)	2 items (6 pts)
3	2	5 items (18 pts)	12 items (36 pts)	-
	3	10 items (30 pts)	1 item (3 pts)	-
4	4	2 items (6 pts)	2 items (6 pts)	-
	5	3 items (9 pts)	4 items (12 pts)	1 item (3 pts)
	6	2 items (6 pts)	2 items (6 pts)	-
5	7	-	1 item (3 pts)	1 item (3 pts)
	8	1 item (3 pts)	1 item (3 pts)	-
	9	1 item (3 pts)	1 item (3 pts)	-
6	10	1 item (3 pts)	1 item (3 pts)	-
	11	1 item (3 pts)	1 item (3 pts)	-
	12	1 item (3 pts)	1 item (3 pts)	-
TOTAL	12	33 items (99 pts)	29 items (87 pts)	4 items (12 pts)

Accordingly, the minimum scores a student can achieve on the scale is 0, while the maximum score is 198. The evaluation of the scale was based on criteria established by the researchers, as presented in Table 5.

Table 5. Evaluation Criteria of the Field Language Scale

Points Received	Evaluation Criteria
0-66	Low
67-132	Medium
133-198	High

The content validity of the Domain Language Scale was confirmed by experts, ensuring alignment with learning outcomes, grade-level appropriateness, and effectiveness in assessing domain language use in decimal notation. For reliability, inter-rater reliability was examined by comparing scores independently assigned by the researcher and a mathematics educator to 25 students' responses. The scores were generally consistent, and discrepancies were resolved through discussion and consensus.

4.4. The Experimental Research Process

The experimental research process was carried out in eight stages as shown in Figure 2.

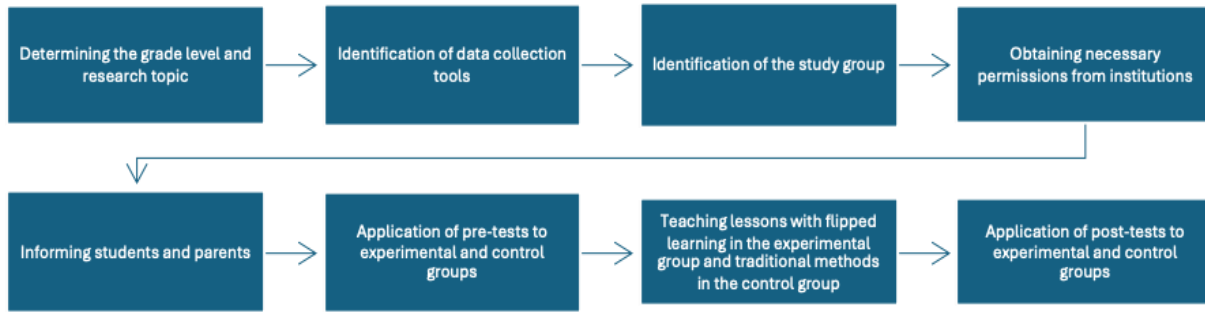


Figure 2. Experimental Research Process

The week-by-week implementations for the experimental group are illustrated in Figure 3.

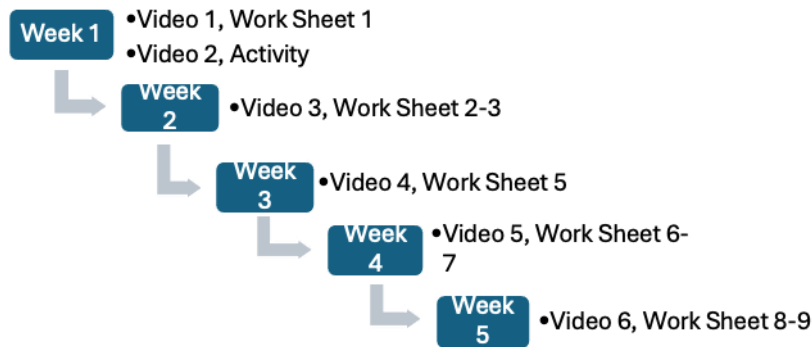


Figure 3. Week by Week Implementations

The videos were evaluated by experts for technological aspects (audio/video quality, platform suitability, screen layout) and mathematical aspects (alignment with learning outcomes, grade-level appropriateness, domain language, content, duration). Based on feedback, the videos were finalized and recorded using Zoom, which allowed simultaneous viewing of the teacher and materials. A graphics tablet was used for clear writing, and the screen layout ensured readability. The videos, shared privately via YouTube over 5 weeks, included questions to engage students actively. Answers were later discussed in class for peer and teacher feedback. Screenshots from the videos are shown in Figure 4.

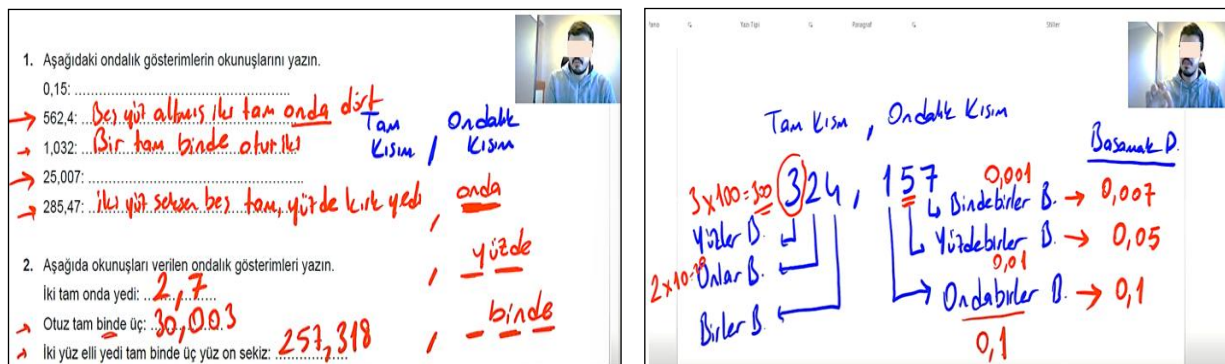


Figure 4. Sample Screenshots of Prepared Videos

The original instructional content displayed in the screenshots is in Turkish. An English translation of the on-screen text is provided in Figure 5.

<p>1. Write the readings of the following decimal numbers. 0.15: 562.4: five hundred sixty-two and four tenths 1.032: one and thirty-two thousandths 25.007: 285.47: two hundred eighty-five and forty-seven hundredths</p> <p>2. Write the decimal representations of the following readings. Two and seven tenths: 2.7 Thirty and three thousandths: 30.003 Two hundred fifty-seven and three hundred eighteen thousandths: 257.318</p>	<p>Whole part – Decimal part Place values: ones, tens, hundreds, tenths, hundredths, thousandths Example: 324.157 3 hundreds 1 tenths 2 tens 5 hundredths 4 ones 7 thousandths</p>
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Figure 5. Translation of the on-screen text

In the flipped learning model, students learn the material by watching videos outside the classroom, allowing in-class time to address misunderstandings, solve problems, and engage in activities. To enhance learning on decimal notation and domain language, the researcher prepared worksheets and activities, which were reviewed and finalized with feedback from experts for alignment with learning objectives and grade-level appropriateness.

4.5. Analyzing the Data

The data were analyzed using IBM SPSS 28.0. The Kolmogorov-Smirnov test checked normality. An Independent Sample t-Test compared pretest scores between experimental and control groups. To analyze changes from pretest to posttest, a difference variable ("Post-test - Pre-test") was created (Gravetter & Wallnau, 2007). Dependent and Independent Sample t-Tests were used to evaluate the significance of these differences. While t-tests identify significant differences, they do not measure their magnitude. To address this, the effect size was calculated using Cohen's (1988) formula.

The interpretation of the effect size was based on critical thresholds delineated on the number line in Figure 5 (Can, 2019; Cohen, 1988; Green & Salkind, 2005).

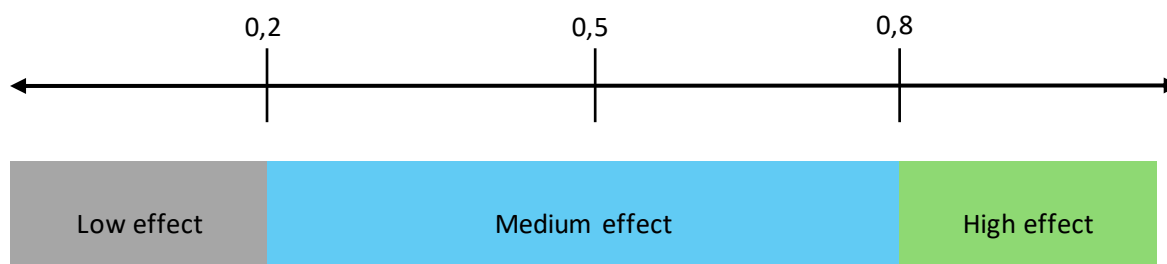


Figure 5. Critical values of effect size

5. Findings

This section presents the findings from the "Decimal Notation Achievement Test" and "Domain Language Scale" to address the research questions.

5.1. Academic Achievement

The first research question investigated whether there was a significant difference in academic achievement between the experimental group (flipped learning model) and the control group (traditional teaching). The Kolmogorov-Smirnov test confirmed normal distribution of pretest and posttest scores ($p > .05$) as shown in Table 6.

Table 6. Normality test results of achievement test pre-test and post-test scores

Test	Variable	Group	Kolmogorov-Smirnov ^a
Pre-test	Achievement	Experimental	.200*
		Control	.188
Post-test		Experimental	.200*
		Control	.200*
Pre-test – Post-test		Experimental	.200*
		Control	.083
Pre-test	Mathematical Symbol Usage	Experimental	.200*
		Control	.200*
Post-test		Experimental	.189
		Control	.178
Pre-test – Post-test		Experimental	.077
		Control	.073
Pre-test	Verbal Expression	Experimental	.200*
		Control	.200*
Post-test		Experimental	.075
		Control	.200*
Pre-test – Post-test		Experimental	.097
		Control	.088
Pre-test	Model and Representation	Experimental	.003
		Control	.012
Post-test		Experimental	.002
		Control	.006
Pre-test – Post-test		Experimental	.194
		Control	.200*

Descriptive statistics regarding the achievement scores of the groups are presented in Table 7;

Table 7. Descriptive statistics of experimental and control group achievement scores

Group	Test	N	X	S
Experimental	Pre-test	49	7.27	2.379
	Post-test	49	13.82	3.302
	Pre-test – Post-test	49	6.55	3.156
Control	Pre-test	49	7.29	2.915
	Post-test	49	11.73	3.915
	Pre-test – Post-test	49	4.45	2.894

Statistical results regarding the achievement scores of the groups are shown in Table 8. The Independent Samples t-Test for the pre-test comparison of the groups (Table 8) showed no significant difference between the pre-test scores of the groups ($p > .05$), indicating equivalent academic achievement at baseline. The control group showed significant improvement in post-test scores ($p < .001$) with a large effect size ($d = 1.537$), indicating traditional teaching improved academic achievement (Table 8). The

experimental group also showed significant improvement ($p < .001$) with a larger effect size ($d = 2.076$), indicating more substantial gains with flipped learning. An Independent Samples t-Test for the post-test comparison of the groups revealed a significant difference in score improvements between the groups ($p < 0.001$), with a medium effect size ($d = 0.694$), showing that the flipped learning model was more effective.

Table 8. Results of experimental and control group achievement scores

Comparison	Test	Sd	t	p
Pre _{control} -Pre _{experimental}	Independent Samples t-test	96	-.038	.485
Pre _{control} -Post _{control}	Dependent Samples t-Test	48	-10.760	<.001
Pre _{experimental} – Post _{experimental}	Dependent Samples t-Test	48	-14.530	<.001
Post _{control} -Post _{experimental}	Independent Samples t-test	96	3.436	<.001

5.2. Mathematical Symbol Use

The second research question explored differences in mathematical symbol use. Pretest and posttest scores were normally distributed ($p > .05$) as seen in Table 6. Descriptive statistics regarding the mathematical symbol usage scores of the groups are presented in Table 9;

Table 9. Descriptive statistics of experimental and control group mathematical symbol usage scores

Group	Test	N	X	S
Experimental	Pre-test	45	19.71	8.885
	Post-test	45	66.13	23.875
	Pre-test – Post-test	45	46.42	21.08
Control	Pre-test	45	19.47	7.928
	Post-test	45	48.98	19.603
	Pre-test – Post-test	45	29.51	17.81

Statistical results regarding the achievement scores of the groups are shown in Table 10. An Independent Samples t-Test showed no significant difference between the groups' pretest scores ($p > .05$), confirming equivalence at the start. The control group showed significant improvement ($p < .001$) with a large effect size ($d = 1.656$). Similarly, the experimental group showed greater improvement ($p < .001$) with a larger effect size ($d = 2.201$), reflecting greater progress with flipped learning. As a result, the experimental group had a higher mean posttest score and a larger effect size than the control group. An Independent Samples t-Test for the post-test comparison of the groups revealed a significant difference in improvement ($p < .001$) with a high effect size ($d = 0.866$), indicating the superiority of flipped learning.

Table 10. Results of experimental and control group mathematical symbol usage scores

Comparison	Test	Sd	t	p
Pre _{control} -Pre _{experimental}	Independent Samples t-test	88	.138	.445
Pre _{control} -Post _{control}	Dependent Samples t-Test	44	-11.111	<.001
Pre _{experimental} – Post _{experimental}	Dependent Samples t-Test	44	-14.767	<.001
Post _{control} -Post _{experimental}	Independent Samples t-test	88	4.109	<.001

5.3. Verbal Expressions

The third research question examined differences in verbal expressions for decimal notation. Pretest and posttest scores were normally distributed ($p > .05$) as seen in Table 6. Descriptive statistics regarding the mathematical verbal expressions scores of the groups are presented in Table 11;

Table 11. Descriptive statistics of experimental and control group verbal expression dimension scores

Group	Test	N	X	S
Experimental	Pre-test	45	17.00	4.661
	Post-test	45	53.31	17.885
	Pre-test – Post-test	45	36.31	16.41
Control	Pre-test	45	17.58	5.233
	Post-test	45	39.07	15.756
	Pre-test – Post-test	45	21.48	16.08

Statistical results regarding the verbal expressions scores of the groups are shown in Table 12. An Independent Samples t-Test showed no significant difference in pretest scores ($p > .05$), confirming equivalence at the start. The control group showed significant improvement ($p < .001$) with a large effect size ($d = 1.336$). On the other hand, the experimental group showed more substantial improvement ($p < .001$) with a larger effect size ($d = 2.211$). The experimental group’s post-test mean score was higher than the control group’s, with a larger effect size, demonstrating the greater impact of the flipped learning model over traditional teaching. An Independent Samples t-Test for the post-test comparison of the groups revealed a significant difference in improvement ($p < .001$) with a large effect size ($d = 0.912$), confirming the greater impact of flipped learning.

Table 12. Results of experimental and control group verbal expression dimension scores

Comparison	Test	Sd	t	p
Pre _{control} -Pre _{experimental}	Independent Samples t-test	88	-.553	.291
Pre _{control} -Post _{control}	Dependent Samples t-Test	44	-8.965	<.001
Pre _{experimental} – Post _{experimental}	Dependent Samples t-Test	44	-14.837	<.001
Post _{control} -Post _{experimental}	Independent Samples t-test	88	4.327	<.001

5.4. Representations with Models

The fourth research question assessed differences in students' ability to represent decimal notation with models. As seen in Table 6 pre-test and post-test scores for representation were not normally distributed ($p < .05$), so the Mann-Whitney U Test was used for pretest analysis. Descriptive statistics regarding the representations with models dimension scores of the groups are presented in Table 13;

Table 13. Descriptive statistics of experimental and control group representation with model dimension scores

Group	Test	N	X	S
Experimental	Pre-test	45	5.24	2.268
	Post-test	45	9.67	1.989
	Pre-test – Post-test	45	4.42	2.29
Control	Pre-test	45	5.24	2.123
	Post-test	45	6.91	2.961
	Pre-test – Post-test	45	1.66	2.94

Statistical results regarding the verbal expressions scores of the groups are shown in Table 14. No significant difference was found between pre-test scores of the two groups ($p > .05$), indicating equivalence at the start. The control group showed significant improvement from pretest to posttest ($p < .001$) with a medium effect size ($d = 0.565$). The experimental group showed greater improvement from pretest to posttest ($p < .001$) with a large effect size ($d = 1.930$). Finally, an Independent Samples t-Test for the post-test comparison of the groups revealed a significant difference in improvement ($p < .001$) with a large effect size ($d = 1.043$), demonstrating the flipped learning model's superiority in this dimension.

Table 14. Results of experimental and control group representation with model dimension scores

Comparison	Test	Statistics		
Pre _{control} -Pre _{experimental}	Mann-Whitney U Test	U=.995	p=.886	
Pre _{control} -Post _{control}	Dependent Samples t-Test	44	-3.794	<.001
Pre _{experimental} – Post _{experimental}	Dependent Samples t-Test	44	-12.948	<.001
Post _{control} -Post _{experimental}	Independent Samples t-test	88	4.952	<.001

The findings consistently show that the flipped learning model significantly outperformed traditional teaching in improving students' academic achievement, use of mathematical symbols, verbal expression, and representation with models in decimal notation.

6. Conclusion

The results showed that students in the flipped learning model outperformed those in the traditional instruction condition in academic achievement on decimal notation; therefore, H1 was supported. In the flipped learning model, students prepared by watching lecture videos at their own pace, enabling better comprehension and leaving more class time for hands-on activities. In contrast, traditional teaching introduced new material during class, leaving limited time for practice and hindering progress due to varied learning speeds. The flipped learning model, encouraged active participation, while traditional teaching relied on passive, presentation-based learning, resulting in fewer solved questions and less effective outcomes.

Research shows that the flipped learning model improves academic achievement in mathematics (Ağırman, 2023; Akdeniz, 2019; Arslan, 2021; Gürer, 2023; Koç Deniz, 2019; Özdemir, 2016; Wei et al., 2020). However, some studies (Aydın, 2020; Camcı, 2022; Doğru, 2022) found no significant impact. Bulut (2019) noted that flipped learning model, enhances higher-level cognitive skills but not lower-level ones. Overall, flipped learning model, appears more effective than traditional methods.

The research highlights that traditional teaching methods effectively improve students' academic achievement in decimal notation and remain widely preferred by educators (Demirkan & Saraçoğlu, 2016; Şensoy & Kılıç, 2021). Despite students taking a passive role, they can connect new concepts to prior knowledge. Factors like teacher self-efficacy, student attitudes (Çavdar, 2019; Çiner & Kılıç, 2022; Elalmış et al., 2023; Kara & Özkaya, 2022), and parental support (Arslan & Nural, 2004; Morrison, 2003) also influence learning. Thus, students can effectively learn decimal notation through traditional methods.

The findings indicated that the flipped learning model led to significantly higher improvement in students' use of mathematical symbols compared to traditional teaching; therefore, H2 was supported. Students solved questions individually and in groups, with errors addressed collaboratively and corrected with teacher guidance when needed. This approach encouraged conscious and accurate use of mathematical symbols and improved understanding through discussion of mistakes.

In traditional teaching, students learned mathematical symbols by rote, with little time for problem-solving or error discussions, limiting effectiveness. In contrast, the flipped learning model's group work and discussions improved students' use of mathematical symbols. Practices like those in Japan, emphasizing group work and communication (Khaing et al., 2007), and frequent exposure to correct symbol usage (Güldal, 2022) further enhance proficiency. This study shows that focused attention on correcting errors significantly improves students' use of mathematical symbols in decimal notation.

The research showed that the flipped learning model significantly enhanced students' verbal expression of decimal notation relative to the control group; therefore, H3 was supported. In flipped learning model, students explained their solutions on the board and during group work, correcting errors collaboratively with teacher support when needed. This interactive approach enhanced their verbal skills. Traditional teaching, focused on teacher-led presentations, offered fewer opportunities for student interaction and expression. Increased participation in flipped learning model, as noted by studies (Çevikbaş, 2018; Kaya, 2018), allowed students to express mathematical ideas more effectively. The teacher's use of student-appropriate language also contributed to this improvement, consistent with Güldal's (2022) findings.

The results demonstrated that the flipped learning model produced significantly greater gains in students' ability to represent decimal notation with models than traditional instruction; therefore, H4 was supported. In flipped learning model, students practiced drawing models on a smart board and in group work, correcting errors collaboratively with teacher guidance. This hands-on approach and use of technology enhanced accuracy and understanding. In contrast, traditional teaching relied on pre-made textbook models, offering limited practice and fewer opportunities to develop model representation skills. Studies like Špilka and Popper (2014) also found that technological tools improve students' use of models, supporting the effectiveness of flipped learning model.

This study found that the flipped learning model significantly improved students' academic achievement and domain-specific language use in mathematics compared to traditional methods, highlighting flipped learning model as an effective teaching approach. Parental support is crucial for its success, as much of the learning takes place outside school. Ensuring student engagement and assignment completion at home can further enhance flipped learning model's effectiveness in improving academic outcomes and mathematical language use.

Parents should be informed about the flipped learning model and the importance of their support before its implementation. Students' access to technology must also be carefully considered. High-quality, interactive lecture videos with animations, games, contests, and Q&A activities are recommended to boost student engagement and interest.

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