Study Protocol and Statistical Analysis Plan

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The Effect of the Flipped Classroom Model on Nursing Students' Pediatric Pain Management Knowledge and Learning Motivation: A Randomized Controlled Trial (FLIPNURSE)

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The Effect of the Flipped Classroom Model on Nursing Students' Pediatric Pain Management Knowledge and Learning Motivation: A Randomized Controlled Trial

Abstract

Aim

The aim of this study is to evaluate the effect of the flipped classroom model on nursing students' knowledge level and learning motivation in pediatric pain management.

Background

Pain management in children is an important and multidimensional responsibility in nursing. However, the time allocated to pediatric pain and the opportunities for practical application in nursing education programs are limited. The integration of active learning approaches is necessary to increase knowledge and motivation in this area.

Design

This study is a parallel-group, randomized controlled experimental study conducted at a state university in Turkey.

Methods

A total of 84 third-year nursing students were randomly assigned to an intervention (n=42) and control (n=42) group. The intervention group was taught using the flipped classroom model, while the control group was taught using the self-directed learning model. Data were collected at three time points (pre-test, post-test, and 3 months post-intervention) and analyzed using a two-way mixed-design ANOVA.

Results

At baseline, there were no significant differences between the groups in terms of knowledge and motivation levels ($p > 0.05$). After the training, significant and sustainable increases were observed in both variables in the intervention group ($p < 0.001$), while no significant changes were observed in the control group.

The group × time interaction was found to be significant for both variables, indicating that the flipped classroom model provides an effective and sustainable contribution to knowledge level and motivation.

Conclusions

Flipped classroom-based instruction emerges as an effective method for enhancing nursing students' knowledge level and learning motivation in pediatric pain management. The integration of this model into nursing education programs is recommended.

Key words: Pediatric Pain Management; Flipped Classroom; Nursing Students; Learning Motivation; Randomized controlled trial

1. Introduction

Pain management in children is an important nursing responsibility that involves not only physiological but also psychological and ethical dimensions. Children hospitalized in hospitals frequently experience pain due to medical interventions, surgical procedures, and chronic diseases (Shah & Siu, 2019). These pain experiences can lead to short-term physiological changes as well as psychological responses such as anxiety and restlessness (Shanmugam et al., 2025). In the long term, they can result in serious consequences such as behavioral disorders, sleep problems, and chronic pain (WHO, 2020).

The assessment and management of pain in pediatric patients is a more complex process compared to adults. This complexity stems from children's pain perception, which varies according to developmental stages, limited verbal expression skills, and individual differences (Shah & Siu, 2019; Kudubeş, Bektaş & Bektaş, 2021). Research indicates that nurses and nursing students have insufficient knowledge and skills regarding pediatric pain management (Ekim & Ocakcı, 2013; Alshehri et al., 2024; Ülgen & Tüfekci, 2024; Shanmugam et al., 2025). This situation is considered an important risk factor that may negatively affect the quality of care for pediatric patients. Therefore, organizations such as the International Association for the Study of Pain (IASP) and the World Health Organization (WHO) are working to increase global awareness of pediatric pain management. Particularly in low- and middle-income countries, they have called for international action to strengthen education in this field (Bond, 2011; Raja et al., 2020).

Nursing students can develop effective pain management skills through a qualified and comprehensive education process (Yuan, 2024). However, the time and resources allocated to pediatric pain management in current nursing programs are insufficient. In particular, limited opportunities for practical training negatively affect students' clinical competence (Ung et al., 2016). This situation may lead to significant deficiencies in future nurses' ability to recognize, assess, and manage pain. Therefore, the integration of alternative teaching methods that deepen learning, increase motivation, and enhance practical skills into the education system is no longer an option but a necessity (Shamsi, 2025).

The flipped classroom model is an innovative teaching approach that supports students in taking a more active role in the learning process and is increasingly accepted in educational sciences (Busebai et al., 2021; Barranquero-Herbosa, Abajas-Bustillo, & Ortego-Maté, 2022). This model is based on students learning theoretical knowledge outside the classroom through online

content and dedicating classroom time to application-based learning activities (Shi et al., 2025; Zhang et al., 2025). Current research in health sciences shows that the flipped classroom approach has positive effects on students. It has been reported that this approach significantly improves students' academic achievement, learning motivation, and critical thinking skills (Betihavas et al., 2016; Liu et al., 2018; Xu et al., 2019; Sureda-Negre, Comas-Forgas & Morey-López, 2019; Merrou et al., 2023; Alshehri et al., 2024).

However, a review of the literature reveals that no randomized controlled trial has yet been conducted to evaluate the effectiveness of the flipped classroom model in the field of pediatric pain management. Current systematic reviews and meta-analyses clearly emphasize that randomized controlled studies on the reverse class approach have primarily focused on general nursing practices or general pediatrics topics; no direct randomized controlled study specifically addressing pediatric pain management has been identified. (Barranquero-Herbosa, Abajas-Bustillo, & Ortego-Maté, 2022; Shi et al., 2025). This gap in the literature highlights the need for empirical studies evaluating the impact of pedagogical innovations in nursing education. This study aims to address this need by examining the effect of the flipped classroom model on nursing students' knowledge level and learning motivation in pediatric pain management.

Research Hypotheses

Hypothesis 1: The pediatric pain knowledge scores of students educated with the flipped classroom model are significantly higher than those of the control group.

Hypothesis 2: The learning motivation scores of students educated with the flipped classroom model are significantly higher than those of the control group.

2. Methods

2.1. Design and Settings

This study was designed as a parallel group randomized controlled trial. The study was conducted with third-year students enrolled in the Nursing Department of a state university in Turkey. The implementation process began in February 2022 and was completed in July 2022. The study was completed according to the planned schedule; there were no interruptions in the education and follow-up processes. No changes were made to the planned methodological approaches during the research process. The research design, measurement timelines, sample criteria, and analysis methods remained consistent throughout the study.

2.2. Instruments

Research data were collected using an individual identification form, a pediatric pain management knowledge scale for nursing students, and a motivation survey regarding teaching materials.

2.2.1. Individual Identification Information Form

This form was prepared by the researchers to assess the demographic characteristics of the students and their self-efficacy perceptions regarding pediatric pain management (Gadallah et al., 2017; Aydın & Bektaş, 2020; Liu et al., 2020).

2.2.2. Pediatric Pain Management Knowledge Scale

This scale was developed by Aydın and Bektaş (2021) to measure nursing students' knowledge levels regarding pediatric pain (Aydın and Bektaş, 2021). High scores on this 5-point Likert scale, consisting of six subdimensions and 29 items, indicate higher knowledge levels. The subscales of the scale include pain awareness with 6 items (items 1, 2, 3, 4, 5, and 29), pain pathophysiology (items 6, 7, 25, and 26), barriers to pain management (items 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, and 18), pain diagnosis 2 items (19 and 20), pain assessment 2 items (20 and 21), and pain control 4 items (23, 24, 27, and 28). The coding of items 3, 6, 8, 10, 11, 12, 13, 14, 15, 17, and 21 in the scale has been reversed. The scale has a minimum score of 29 and a maximum score of 145, with higher scores indicating that students have more knowledge about Pediatric Pain Management. The reliability coefficient of the scale is 0.864. In this study, the Cronbach's alpha coefficient of the scale was calculated as 0.845.

2.2.3. Motivation Questionnaire Regarding Teaching Materials

The Teaching Material Motivation Survey (ÖMMA) was developed by Keller and its validity and reliability were studied in Turkish by Kutu and Sözbilir (Keller, 2006; Kutu & Sözbilir, 2011). This scale, which aims to determine students' motivation levels toward instructional materials, consists of a total of 24 items on a 5-point Likert scale. The items in the attention-appropriateness dimension of the ÖMMA are 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11; while the items in the confidence-satisfaction dimension are 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, and 24. Five items in the questionnaire (3, 12, 14, 16, 18) were reverse-coded. The minimum score in the questionnaire is 24, and the maximum score is 120. A high score on the survey indicates high motivation regarding the teaching material. The Cronbach's alpha coefficient is 0.83. In this study, the Cronbach's alpha value was found to be 0.789.

2.3. Sample, randomization, and prevention of bias

The population of this study consisted of a total of 152 third-year nursing students enrolled in the Child Health and Nursing course. Sample size and power analysis were performed using the G*Power 3.1.9 program. Considering the research design (three measurements and two groups), the following parameters were used for the ANOVA test in repeated measurements: $\alpha = 0.05$, power $(1-\beta) = 0.80$, and moderate effect size ($f = 0.25$). Accordingly, a minimum of 27 participants per group and a total of at least 54 participants were required. Considering potential data losses, the study was conducted with 44 participants in each group (Cohen, 2013; Faul et al., 2009).

Students were divided into two groups using stratified sampling based on their academic achievement levels. Those with an academic grade point average between 2.00 and 3.00 formed the first stratum, while those with a grade point average between 3.01 and 4.00 formed the second stratum. Within each stratum, participants were assigned to either the intervention or control group in equal numbers using a computer-assisted simple random assignment method with blind allocation. The randomization process was conducted by an independent biostatistician not involved in the study, and no blocking randomization or other restriction methods were used.

The study's sampling process, group distribution, randomization, follow-up, and number of samples analyzed are presented in Figure 1 in accordance with the CONSORT 2010 guidelines. Statistical analysis and reporting were performed by an independent statistician. Since the intervention was directly integrated into the students' educational process in this study, blinding could not be applied from the perspective of the participants (students) and the researchers who administered the intervention. However, to minimize bias, blinding was ensured during the data analysis process. In this context, a data set that did not contain information about which intervention the groups received, but was only coded (e.g., Group A, Group B) and anonymized, was presented to the independent statistician; the statistician conducted the analyses without knowing the identity of the groups. Thus, objectivity was maintained and the risk of systematic bias was reduced during the analysis and reporting stages. Additionally, a chi-square test based on academic achievement scores was conducted to assess the homogeneity of the groups at the baseline level, and it was determined that the groups were at a similar level (Table 1).

2.4. Inclusion and Exclusion Criteria

The inclusion criteria were as follows: (1) taking the Child Health and Nursing course for the first time, (2) having access to the internet and a computer or smartphone, (3) agreeing to take the concurrent courses on the Google Classroom platform, (4) agreeing to participate in the study voluntarily.

Exclusion criteria were as follows: (1) having previously received training in pediatric pain management, (2) withdrawing consent during the study, (3) failing to complete any stage of the intervention or data collection process.

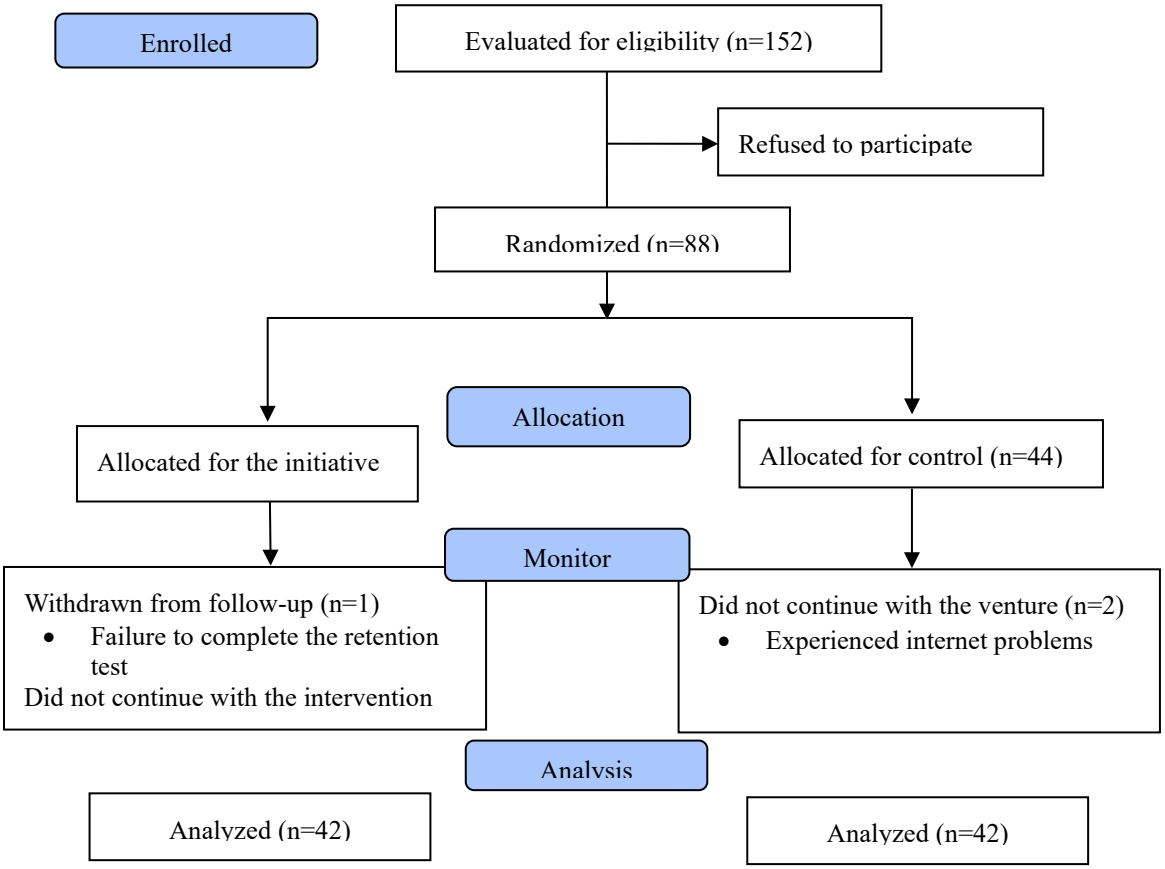

Figure 2. CONSORT Flow Chart

2.5. Preparation of the program

Since there is no standard training module on pain management in children, the training content was prepared by researchers based on a literature review (Büyükgönenç & Törüner, 2018; IASP, 2018; ChildKind International, 2020; WHO, 2012; WHO, 2020). The content was evaluated by 10 faculty members specializing in pediatric nursing and revised based on their feedback. Presentations were prepared and video lessons were created based on this content. In the study, the same training programs were prepared for the intervention and control groups. Weekly

topics and training duration were kept equal for both groups. Teaching methods and techniques were structured based on the "Flipped Classroom Model" for the intervention group and the "Self-Directed Learning Model" for the control group.

The training process lasted four weeks, with each week focusing on a different topic:

1. Week 1: Introduction to pain,
2. Week 2: Pathophysiology of pain and management challenges,
3. Week 3: Diagnosis and assessment,
4. Week 3: Pain control.

2.6. Application of the flipped learning approach in the intervention group

Students in the intervention group watched lecture videos on relevant topics one week before classroom activities. Students accessed the lecture videos through the https://www.e-pediatri.com platform, developed by researchers using the Tutor LMS system. Tutor LMS was chosen as an effective learning management system due to its user-friendly mobile-supported interface, flexible configuration options, and comprehensive monitoring and evaluation tools. Students logged into the platform with their username and password to access course materials anytime and anywhere and review the materials repeatedly.

Classroom activities were conducted once a week for four weeks, consisting of online sessions lasting approximately 20-25 minutes. These sessions were conducted using interactive techniques in line with the flipped learning approach via the Google Classroom infrastructure integrated into the https://www.e-pediatri.com platform. In the classroom sessions, various student-centered activities such as mini tests, case studies, article reviews, concept maps, and group discussions were implemented to ensure active student participation. These methods were used to help students understand the topics in terms of cause-and-effect relationships and to increase the retention of learning.

2.7. Application of the self-directed learning approach to the control group

The same educational videos were uploaded simultaneously to the university's Distance Education Center (UZEM) platform for the students in the control group. Students were allowed to watch the videos individually, and no online classroom interaction was conducted throughout the process. The learning process was supported by assignments given to students and online educational materials. The assignments completed by students were evaluated, and feedback was provided to them. The duration of the training was kept equal for both groups.

To minimize contamination risk, the intervention group's training was conducted through the e-pediatri.com platform, while the control group's training was conducted through the university's UZEM platform in sessions of equal duration.

2.8. Data collection

In the study, pre-tests were administered before the training; post-tests were administered one month after the completion of the training modules, and retention tests were administered three months after the completion of the training.

All data collection for the intervention and control groups was conducted online. The questionnaires and scales used were distributed to participants via Google Forms, and students were asked to fill out the forms on their own devices. No changes were made to the primary (pediatric pain management knowledge level) and secondary (learning motivation) outcome measures defined at the beginning of the study during the data collection process.

2.9. Ethical considerations

The research was conducted in full compliance with the ethical principles of the Helsinki Declaration. Institutional permission and ethical committee approval (Meeting/Decision Number: 10/01; Protocol No: 1070, Date: August 31, 2021) were obtained from the relevant unit of the university where the research was conducted. Prior to data collection, all participants were provided with written information about the purpose, scope, and voluntary nature of the study, and informed consent was obtained. Participants' personal information was kept confidential, and data were used solely for academic purposes. Additionally, the necessary written permissions were obtained from the copyright holders of the measurement tools used in the study.

2.10. Data analysis

Data analysis was performed using IBM SPSS 25.0 (IBM Corp., Armonk, NY, USA). The assumption of normal distribution was evaluated using the Kolmogorov–Smirnov test and supported by skewness and kurtosis values within the ±2 range. The internal consistency of the scales was determined using Cronbach's alpha coefficient.

Within the scope of statistical analysis, frequency distributions and descriptive statistics were calculated; independent samples t-test and chi-square test were used for intergroup comparisons. Two-Way Mixed ANOVA was applied to examine the effects of group, time, and group × time interaction on education. All necessary assumptions (e.g., normal distribution,

variance homogeneity, sphericity) were tested and found to be met in this analysis. The significance level was set at p<0.005 for all statistical analyses. Additionally, no subgroup analyses were conducted for variables such as age, gender, or academic achievement. All analyses were designed to focus on between-group comparisons.

3. Results

3.1. Intergroup Comparison of Descriptive Characteristics of Students

The descriptive characteristics of students in the intervention and control groups (n=84) are presented in Table 1. No significant differences were found between the groups in terms of age, gender, academic grade point average, and pain management self-assessment scores (p>0.05).

Table 1. Descriptive Characteristics of Students

Descriptive Characteristics	**Intervention Group**		**Control Group**		**t**	**p**
	$\bar{X}$±SS (Min – Max)		**$\bar{X}$±SS (Min – Max)**			
Age	22.19 ± 2.32 (20–31)		21.86 ± 1.64 (20–29)		0.757	0.125
Pain management self-assessment (0-10 points)	4.52 ± 1.19 (2-7)		4.33 ± 1.05 (2-6)		0.776	0.333
Gender	**n**	**%**	**n**	**%**	**Chi-square**	**p**
Female	31	73.8	27	64.3	0.345	0.891
Male	11	26.2	15	35.7		
Academic grade point average						
2.00–3.00	21	50	21	50.0	0.001	1.00
3.01–4.00	21	50.0	21	50		
t: Independent samples t-test, chi-square test						

3.2. Findings Related to the Level of Knowledge About Pediatric Pain Management

According to the pre-test results, there was no significant difference between the intervention group and the control group in terms of pediatric pain management knowledge level ($p > 0.05$). However, according to the two-way mixed design ANOVA analysis, group effect ($F=16.789$, $p < 0.001$, $\eta^2=0.170$), time effect ($F=23.251$, $p<0.001$, $\eta^2=0.221$), and group*time interaction ($F=27.834$, $p<0.001$, $\eta^2=0.253$) were found to be statistically significant. In particular, the significance of the group*time interaction indicates that the two groups showed different patterns of change in their knowledge levels over time (Table 2).

In the intervention group, a significant increase was observed in students' pediatric pain management knowledge scores. The mean score, which was 78.04±18.79 in the pre-test, increased to 105.92±23.62 in the post-test and was recorded as 92.26±23.40 in the retention

test. The use of different letters (a, b, c) to denote the means obtained at different measurement times indicates statistically significant differences over time. However, in the control group that received education using the self-learning model, the knowledge level scores remained quite close to each other over time, and no significant change was detected (pre-test: 79.33±19.19, post-test: 78.09±14.68, retention test: 77.16±15.94). These findings indicate that the flipped classroom model is more effective than the self-directed learning model in improving knowledge levels in pediatric pain management and ensuring the retention of this knowledge (Figure 1).

Table 2. Pediatric Pain Management Knowledge Level Scores of the Intervention and Control Groups

Pediatric Pain Management Knowledge Scale	**Intervention group (n=44)**	**Control group (n=44)**	**Statistic**	**Group**	**Time**	**Group*time interaction**
	Mean (SD)	**Mean (SD)**				
Pre-test	78.04 (18.79)[a]	79.33 (19.19)[a]	F	16,789	23,251	27,834
Post-test (4th week)	105.92 (23.62)[b]	78.09 (14.68)[a]	p	<0.001	<0.001	<0.001
Retention Test (3rd month)	92.26 (23.40)[c]	77.16 (15.94)[a]	η^2	0.170	0.221	0.253
a-c: Different letters indicate statistically significant groups within each column. F: two-way mixed design analysis of variance; η^2, partial eta square; SD, standard deviation.						

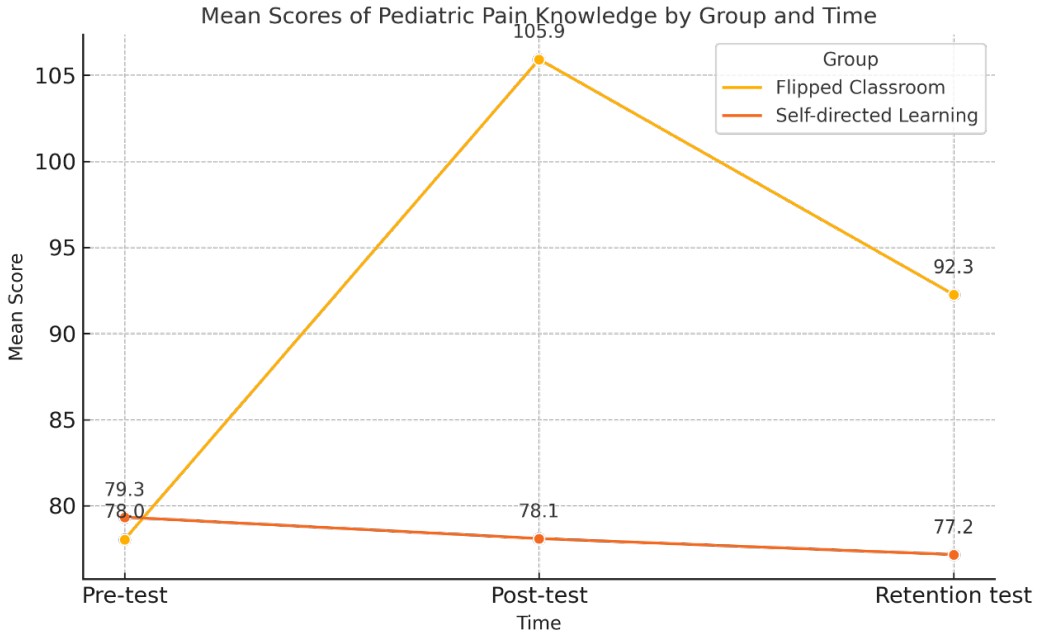

Figure 1. Mean Scores of Pediatric Pain Knowledge by Group and Time

3.3. Findings Related to Motivation Levels

Findings related to students' motivation levels are summarized in Table 3. There was no significant difference in motivation level scores between students in the intervention group and those in the control group in the pre-test ($p > 0.05$). However, when the results of the two-way mixed design ANOVA were examined, group effect ($F=39.206$, $p < 0.001$, $\eta^2=0.323$), time effect ($F=67.749$, $p<0.001$, $\eta^2=0.452$), and group*time interaction ($F=70.240$, $p<0.001$, $\eta^2=0.461$) were found to be statistically significant. The significance of the group*time interaction indicates that the effect of the time factor on motivation levels is not the same for both groups (Table 3).

In the entrepreneurial group that received education with the flipped classroom model, a significant increase was observed in students' motivation scores. The average score, which was 83.61±12.61 in the pre-test, increased to 120.66±17.20 in the post-test and was recorded as 101.50±12.26 in the retention test. The use of different letters (a, b, c) to denote the averages at different measurement times indicates statistically significant differences over time. In contrast, the motivation level scores of the control group, which received education using the self-learning model, remained quite close to each other at all time points, and no significant change was observed (pre-test: 86.76±12.03, post-test: 86.40±11.91, retention test: 85.61±12.36). These findings indicate that the flipped classroom model is more effective than the self-directed learning model in enhancing students' motivation (Figure 2).

Table 3. Learning Motivation Scores of the Intervention and Control Groups

Motivation Survey Regarding Teaching Materials	**Intervention group (n=44)**	**Control group (n=44)**	**Statistic**	**Group**	**Time**	**Group*time interaction**
	Mean (SD)	**Mean (SD)**				
Pre-test	83.61 (12.61)[a]	86.76 (12.03)[a]	F	39,206	67,749	70,240
Post-test (4th week)	120.66 (17.20)[b]	86.40 (11.91)[a]	p	<0.001	<0.001	<0.001
Retention Test (3rd month)	101.50 (12.26)[c]	85.61 (12.36)[a]	η^2	0.323	0.452	0.461
a-c: Different letters indicate statistically significant groups within each column. F: Two-way mixed design analysis of variance; η^2, partial eta square; SD, standard deviation.						

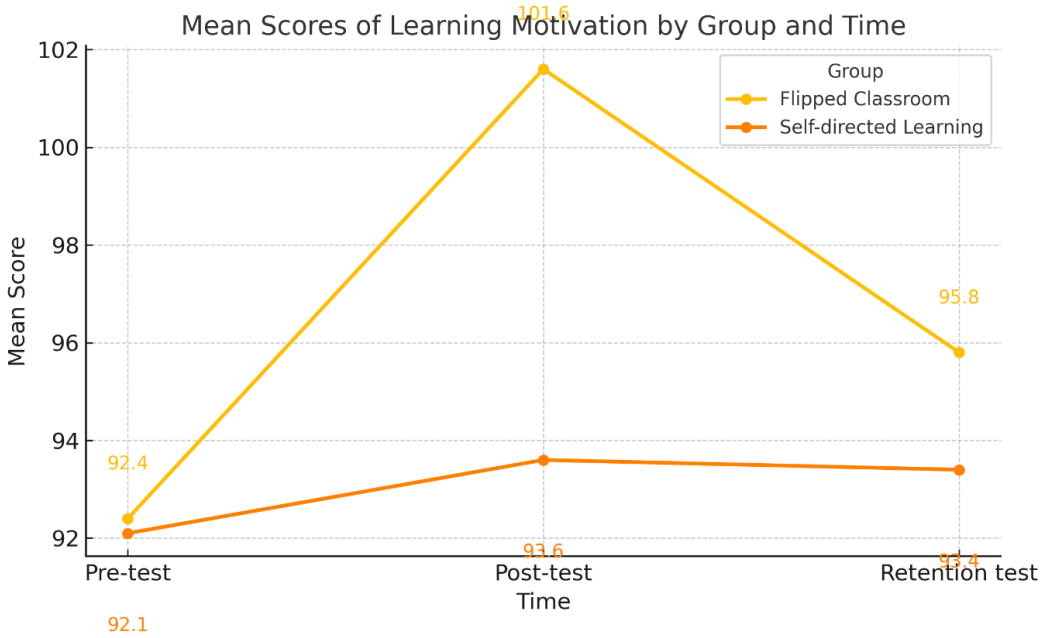

Figure 2. Mean Scores of Learning Motivation by Group and Time

4. Discussion

4.1. The Effect of the Flipped Classroom Model on Pediatric Pain Knowledge Level

A statistically significant and sustained increase in the knowledge levels of nursing students regarding pediatric pain management was observed in those who received education through the flipped classroom model. In particular, the high scores in the retention test compared to the pre-test level indicate the sustainability of learning in the long term. This can be attributed to the flipped classroom model's structure, which encourages active student participation, and its provision of application-based learning environments (Liu et al., 2018; Xu et al., 2019).

These results are consistent with the existing literature. The flipped classroom approach has been shown to enhance knowledge levels in nursing and medical education through various studies (Betihavas et al., 2016; Barranquero-Herbosa, Abajas-Bustillo, & Ortego-Maté, 2022; Merrou et al., 2023). Especially in clinical and applied fields, this model, supported by case analyses, problem-based learning, and group discussions, is reported to enable students not only to acquire knowledge but also to develop their abilities to analyze, evaluate, and transfer knowledge (Liu et al., 2018; Xu et al., 2019; Merrou et al., 2023; Alshehri, Levett-Jones, & Pich, 2024).

The learning gains in question are not limited to quantitative increases in knowledge but also reflect cognitive depth. In this context, the findings can also be evaluated within the framework of Bloom's cognitive domain taxonomy. The flipped classroom model contributes to the activation of higher-order cognitive processes such as analysis, synthesis, and evaluation

beyond the levels of knowledge and comprehension ( ). Similarly, in a study by Paralikar et al. (2022), it was noted that students who participated in the flipped classroom model showed significant development in Bloom's higher cognitive levels and achieved success, particularly in the application and analysis levels. It is stated that this model facilitates students' access to basic knowledge through offline preparation and reinforces their knowledge with higher-order thinking skills in an interactive classroom environment (Paralikar et al., 2022).

In addition to these comprehensive cognitive contributions, the uniqueness of the study area is also noteworthy. The limited number of studies evaluating the effectiveness of the flipped classroom model in narrow and clinically critical areas such as pediatric pain management using a randomized controlled design increases the contribution of the findings to the literature.

The findings indicate that the flipped classroom approach is more effective than the traditional self-learning model in terms of increasing and maintaining knowledge levels in both the short and long term. This result shows that active classroom interaction and practical work carried out after the pre-learning process contribute positively to the retention of learning. Indeed, studies conducted by Sáiz-Manzanares et al. (2020) also emphasize that learning environments with high levels of active participation have a significant impact on knowledge retention (Sáiz-Manzanares et al., 2020).

However, some limitations of this model have also been noted in the literature. In particular, it has been pointed out that factors such as difficulty in accessing digital materials and insufficient assumption of individual learning responsibility may negatively affect student motivation (Busebai & John, 2021). However, in this study, maintaining a strong technical infrastructure and ensuring high accessibility of the digital platform used minimized such negative effects and supported the effectiveness of the learning process.

4.2. The Effect of the Flipped Classroom Model on Learning Motivation

Statistically significant increases in the motivation levels of students who received education through the flipped classroom model were recorded in both the short and long term. In contrast, no significant change in motivation scores was observed in the control group where the self-directed learning model was applied. These findings indicate that the flipped classroom approach is effective in increasing students' interest in the material, encouraging active participation in class, and supporting intrinsic motivation.

In the literature, the positive effect of the flipped classroom model on learning motivation is supported by various studies. According to systematic reviews and meta-analyses conducted by Betihavas et al. (2016) and Liu et al. (2018), flipped classroom models have been found to have significant positive effects on learning motivation, autonomy, and self-efficacy ( ). In particular,

applications supported by case-based and problem-focused learning methods are noted to more effectively engage students in the learning process and enhance motivation (Merrou et al., 2023).

However, studies also highlight that this positive effect on motivation is not always sustainable. Some findings have revealed that the flipped classroom model creates high motivation among students in the initial stage, but motivation decreases over time when digital content is presented in an uninteractive, repetitive, or inadequate manner (Lo & Hew, 2019; Betihavas et al., 2016). This situation demonstrates that not only the structure of the learning model but also the quality of the content presented and the level of interaction are decisive factors in the sustainability of motivation.

Among the key factors that enable motivation to be sustained in the long term are the timeliness of content, diversity of applications, active participation of students in the learning process, and quality of interaction with instructors (Chen et al., 2014; Martin et al., 2020). Indeed, in this study, the fact that motivation scores remained high even in the retention test compared to the initial level suggests that the pedagogical quality of the content design and the intensity of interaction in the learning environment played a supportive role in motivation.

5. Nursing Education Implications

The findings of this study suggest that the integration of the flipped classroom model into the pediatric nursing course has the potential to increase both students' knowledge levels and learning motivation. Especially in teaching topics that require clinical skills, using pedagogical approaches that prioritize student participation alongside traditional methods can support a more effective and lasting learning process.

The flipped classroom model can contribute to the development of students' higher-order cognitive skills, such as critical thinking, decision-making, and problem-solving, in the teaching of multidimensional and complex content such as pediatric pain management. In this regard, the model can guide nursing educators in reviewing their curricula, diversifying their teaching strategies, and integrating active learning-based approaches into their course content.

Furthermore, thanks to digital content support and remote access opportunities, the flipped classroom model has the potential to increase both academic achievement and intrinsic learning motivation by providing flexible learning environments tailored to students' individual learning speeds. This can contribute to strengthening student-centered and interaction-based learning experiences in nursing education.

6. Conclusion

This study revealed that the flipped classroom model significantly increased nursing students' knowledge levels regarding pediatric pain management and their learning motivation toward teaching materials in the short and medium terms. The findings emphasize the importance of integrating pedagogical approaches based on student-centered and active participation into nursing education, going beyond traditional teaching methods.

The flipped classroom model is an innovative teaching strategy that allows students to acquire theoretical knowledge at their own pace while allocating classroom time to deeper learning, discussion of clinical examples, and development of practical skills. In this regard, the model appears to be effective in teaching topics that require critical thinking and clinical decision-making skills, such as pediatric pain management.

The use of this approach in practice-based courses such as pediatric nursing can positively influence not only students' knowledge levels but also their motivation and attitudes toward learning. In this regard, giving more space to innovative learning approaches such as the flipped classroom model in nursing curricula will contribute to the development of students' academic achievements as well as their clinical competence after graduation.

Future research focusing on evaluating the long-term effects of the flipped classroom model in different nursing courses and examining its outcomes on students with different learning profiles will contribute to strengthening evidence-based data on the model's effectiveness.

7. Limitations and strengths

One of the prominent strengths of this study is its randomized controlled experimental design, which was structured to test the research hypotheses. The statistical similarity of the intervention and control groups in terms of their initial descriptive characteristics increased the internal validity of the group comparisons. The validity and reliability of the measurement tools used have been previously reported, supporting the quality of the data obtained. The intervention protocol was structured, developed based on expert opinions, and implemented with equal content and duration for both groups. The use of two different digital platforms (e-pediatri.com and UZEM) to minimize contamination risk was supported by careful planning of synchronization and access timing. Additionally, the statistical analyses were conducted by an independent expert, and the study results were reported in accordance with the CONSORT 2010 ( ) checklist, which are among the factors enhancing the methodological strength of the study.

On the other hand, the study has some limitations. The fact that the research was conducted at a single center and included only nursing students from one university limits the generalizability

of the findings to other institutions or samples. The inability to ensure participant and practitioner blinding may increase the risk of observational bias; however, the fact that the analysis process was conducted blind by an independent statistician partially mitigates this limitation. The fact that learning outcomes were assessed solely using self-report scales, without being supported by behavioral or performance-based objective measures, narrows the scope of the study's evaluation. Additionally, the sustainability assessment covered only a three-month period, so data on long-term effects could not be obtained. The sample consisting solely of third-grade students also prevented comparisons of the model's effects across different grade levels.

Despite these limitations, the study's experimental design, intervention implementation integrity, measures taken to control for bias, and high reporting quality demonstrate that the research was conducted at a methodologically robust and reliable level.

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CRediT authorship contribution statement

Mustafa Belli: Writing – review & editing, Writing – original draft, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Zümrüt Başbakkal: Writing – review & editing, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis.

Declaration of generative AI and AI-assisted technologies in the writing process

While preparing this work, the author(s) used ChatGPT (GPT-4) to enhance the manuscript's language clarity and readability. After using this tool, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the publication's content.

Declaration of Competing Interest

All authors declare that they have no financial or personal relationships that could inappropriately influence or bias their work. Specifically, none of the authors have potential conflicts of interest, such as employment, consultancies, stock ownership, honoraria, paid expert testimony, patent applications, or grants.

Protocol

The full protocol is not publicly available but can be obtained upon reasonable request.

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