

# **The Effect of Artificial Intelligence on Secondary School Students' Self-Learning of Fractions**

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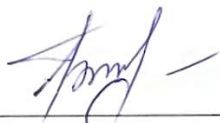


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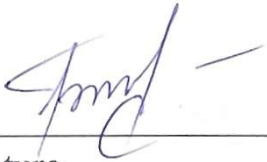
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## **List of Abbreviations**

AI – Artificial Intelligence  
ANS – Approximate Number System  
BKT – Bayesian Knowledge Tracing  
CIS – Commonwealth of Independent States  
CLT – Cognitive Load Theory  
COPEs – Conditions, Operations, Products, Evaluations, Standards  
DTT – Diffusion Tensor Tomography  
fMRI – Functional Magnetic Resonance Imaging  
IPS – Intraparietal Sulcus  
ITND – Integrated Theory of Numerical Development  
ITS – Intelligent Tutoring System  
KMO – Kaiser–Meyer–Olkin measure  
MSLQ – Motivated Strategies for Learning Questionnaire  
OECD – Organisation for Economic Co-operation and Development  
PFA – Performance Factor Analysis  
PISA – Programme for International Student Assessment  
RCT – Randomized Controlled Trial  
SRL – Self-Regulated Learning  
STEM – Science, Technology, Engineering, and Mathematics  
TIMSS – Trends in International Mathematics and Science Study  
UNESCO – United Nations Educational, Scientific and Cultural Organization  
WNB – Whole Number Bias  
ZPD – Zone of Proximal Development

## ABSTRACT

This study examines the effect of an artificial intelligence-based intelligent tutoring system (MATHOS AI) on academic achievement in fractions and self-regulated learning among Grade 5 secondary school students. The research design includes an achievement test and a questionnaire measuring self-regulated learning (MSLQ). The study involved two groups: the control group received traditional instruction, while the experimental group was taught using the MATHOS AI platform. The study aimed to analyze the differences between the experimental and control groups in understanding fractions and developing self-regulated learning. The primary focus of the research was to measure students' academic achievement and the development of their metacognitive skills.

The results of the study demonstrate that instruction based on MATHOS AI has a positive effect on both academic achievement in fractions and the development of self-regulated learning among students. These findings confirm the importance of implementing intelligent tutoring systems, such as MATHOS AI, in mathematics education programs in Kazakhstani schools.

*Keywords: MATHOS AI, fractions, secondary school students, self-regulated learning, academic achievement, intelligent tutoring systems*

## АНДАТПА

Бұл зерттеу жасанды интеллектке негізделген интеллектуалды оқыту жүйесінің (MATHOS AI) бөлшектер тақырыбы бойынша академиялық жетістікке және 5-сынып оқушыларының өзін-өзі реттелетін оқуын дамытуға әсерін қарастырады. Зерттеу дизайны академиялық жетістік тестінен және өзін-өзі реттелетін оқуды (MSLQ) өлшеуге арналған сауалнамадан тұрды. Зерттеуге екі топ қатысты: бақылау тобы дәстүрлі әдіспен оқытылса, эксперименттік топ MATHOS AI платформасын пайдалану арқылы оқытылды.

Зерттеудің мақсаты – эксперименттік және бақылау топтарының бөлшектерді түсінуі мен өзін-өзі реттелетін оқуын дамытуындағы айырмашылықтарды талдау. Зерттеудің негізгі бағыты оқушылардың академиялық жетістіктерін және олардың метатанымдық дағдыларының дамуын анықтау болды.

Зерттеу нәтижелері MATHOS AI негізіндегі оқытудың оқушылардың бөлшектер тақырыбы бойынша академиялық жетістіктеріне және өзін-өзі реттелетін оқуын дамытуға оң әсер ететінін көрсетті. Алынған нәтижелер Қазақстан мектептерінің математикалық білім беру бағдарламаларына MATHOS AI сияқты интеллектуалды оқыту жүйелерін енгізудің маңыздылығын растайды.

*Түйінді сөздер: MATHOS AI, бөлшектер, орта мектеп оқушылары, өзін-өзі реттелетін оқу, академиялық жетістік, интеллектуалды оқыту жүйелері.*

## АННОТАЦИЯ

Данное исследование рассматривает влияние интеллектуальной обучающей системы на основе искусственного интеллекта (MATHOS AI) на академические достижения по теме дробей и развитие саморегулируемого обучения у учащихся 5 класса средней школы. Дизайн исследования включал тест академических достижений и анкету для измерения саморегулируемого обучения (MSLQ). В исследовании приняли участие две группы: контрольная группа обучалась традиционным методом, тогда как экспериментальная группа обучалась с использованием платформы MATHOS AI.

Целью исследования являлся анализ различий между экспериментальной и контрольной группами в понимании дробей и развитии саморегулируемого обучения. Основное внимание исследования было направлено на измерение академических достижений учащихся и развитие их метакогнитивных навыков.

Результаты исследования показали, что обучение на основе MATHOS AI оказывает положительное влияние как на академические достижения по теме дробей, так и на развитие саморегулируемого обучения учащихся. Полученные результаты подтверждают важность внедрения интеллектуальных обучающих систем, таких как MATHOS AI, в программы математического образования школ Казахстана.

*Ключевые слова: MATHOS AI, дроби, учащиеся средней школы, саморегулируемое обучение, академические достижения, интеллектуальные обучающие системы.*



functions, trigonometry, and probability theory. On the contrary, a student with conceptual gaps in the concept of fractions "transfers" these gaps to all subsequent mathematical topics. This is related to Siegler et al. (2012) statistically proven by a longitudinal study conducted in the United States and Great Britain: the level of knowledge of fractions in the 5th grade predicts overall mathematical success in high school ( $\beta = 0.37$ ,  $p < 0.001$ ). Since a similar study was not conducted in Kazakhstan, the need to study this relationship on the basis of national data is obvious.

From the point of view of cognitive science, fractions directly contradict the intuitive schemes that children have formed for natural numbers. Ni and Zhou (2005) called this phenomenon the "Whole Number Bias" (WNB), a major cognitive barrier to mastering fractions. Subsequent studies (Vamvakoussi et al., 2018; González-Forte et al., 2020; Hoof et al., 2021) have confirmed that procedural exercises alone are not sufficient to overcome this barrier without conceptual retraining. It is this pedagogical need that makes the importance of learning approaches based on personalized, adaptive and instant feedback even more important.

Intelligent Tutoring Systems (ITS) provide a unique opportunity to meet these needs. A meta-analysis by VanLehn (2011) found that students using ITS performed on average 0.76 standard deviations higher than their peers in the traditional classroom - higher performance between pedagogical interventions. However, this review looked at ITS in terms of overall effectiveness; there are almost no specific studies that examine the effectiveness of ITS in learning fractions, especially in the context of Central Asia and Kazakhstan. This research gap defines the scientific subject of this dissertation.

Research problem and scientific gap is formulated through three levels of contradictions.

The first contradiction is the gap between technological capabilities and pedagogical effectiveness. Although the digital infrastructure of Kazakhstan's schools has improved significantly, there is no experience of using AI-based platforms combined with didactic principles in teaching mathematics. Since there is no research

on this issue in the national context, teachers cannot properly use AI in a pedagogical context.

The second contradiction is the gap between the cognitive complexity of fractional numbers and the limited number of hours in the school curriculum. The mathematics program of the 5th grade of the Kazakhstan comprehensive School devotes 36-40 hours to the section "fractions". However, research shows that mastering the conceptual aspect of fractions requires three to four times more cognitive processing than mastering natural numbers (Siegler & Pyke, 2013). This inequality leads teachers to resort to algorithmic exercises instead of deepening the content, which leads to a conceptual gap like "can calculate, but does not understand".

The third contradiction is the gap between the age-related cognitive development of students in grades 5-6 and the unified nature of traditional education. Executive functions (planning, working memory management, cognitive flexibility) of 11-13-year-olds on the threshold of adolescence differ significantly at the level of biological maturity and personality (Uus et al., 2021). Traditional classroom teaching does not take into account these individual differences; adaptive AI-based systems can theoretically solve this problem, but in the case of Kazakhstan, this potential in learning fractions has not been tested empirically.

The central research question arising from these three contradictions is: does the use of the MATHOS AI intelligent system affect the academic achievements and self-regulation of 5th grade students when teaching fractions compared to traditional teaching methods?

In the international scientific discourse, research in this area is divided into three groups. The first group examines the impact of ITS on overall mathematical success (VanLehn, 2011; Kulik & Fletcher, 2016)-although positive results were reported ( $d = 0.60 - 0.79$ ), the data were not classified by specific topic. The second group is devoted to cognitive-psychological aspects of learning fractions (Ni & Zhou, 2005; Vamvakoussi & Vosniadou, 2004; Hoof et al., 2021) - barriers are well described, but ITS as a solution has not been tested. A third group links ITS to real-world fraction

themes (Pappas & Drigas, 2016; MacLellan et al., 2024; Shih et al., 2023) - but research has been conducted in Western schools; similar work has not been published in the context of Central Asian or post-Soviet secondary education systems. The intersection of these three groups-a study in the context of Kazakhstan-clearly outlines the scientific gap that this dissertation fills.

### **Purpose and objectives of the study.**

The aim of the study is to provide theoretical justification, experimental verification and determination of the conditions for effective use of the pedagogical and psychological impact of adaptive learning technologies based on artificial intelligence on self-regulated learning of fractions by students of grades 5 of general education schools in Almaty.

To achieve this goal, the following tasks were set:

- Conducting a systematic theoretical analysis of domestic and foreign scientific papers on the cognitive and psychological difficulties of learning fractions, including the phenomenon of Whole Number Bias.
- Pedagogical substantiation of the application of the principles of "scaffolding-fading" and "fast feedback" to the training of fractions, determination of their theoretical connection with the Zimmerman model.
- Operationalization of the "self-proficiency in fractions" constructor using three dimensions: conceptual accuracy, procedural skills, and metacognitive control-and the choice of psychometric tools.
- Conducting a quasi-experimental study in grades 5 of Almaty schools comparing the level of fraction mastery between an experimental group using an AI platform and a control group receiving traditional training.
- To analyze the differentiated effect of rapid feedback mechanisms on students' metacognitive skills (planning, self-control, and reflection) depending on their initial level of achievement.

**Research methods:**

1. Quasi-experimental quantitative method. The study used a quasi-experimental design with parallel groups. The experimental group (EG) used the MATHOS AI intelligent learning platform, while the control group (CG) studied in a traditional classroom environment. This method was used as a study of consolidating knowledge and filling gaps in learning in order to assess the preservation and assimilation of concepts on the subject of fractions previously studied in the school curriculum.

2. The theoretical method. A systematic review and content analysis of fundamental and modern academic literature, peer-reviewed scientific research and international articles was conducted. The theoretical basis of the research was based on the Zimmerman model of Self-Regulated Learning (SRL), Sweller Cognitive Load Theory (CLT), Vygotsky Zone of Proximal Development (ZPD), as well as international approaches to intelligent learning systems (ITS).

3. Empirical and statistical methods Assessment tools. To determine the initial level of academic preparation of students, a pre-test was conducted on the topic of fractions. After the intervention was completed, a similar post-test was used to assess knowledge retention and cognitive growth.

Psychometric assessment. After the intervention was completed, the adapted Motivated Strategies for Learning Questionnaire (MSLQ) was used to assess the formation of components of self-regulated learning, including Planning, Self-Monitoring and Self-Reflection.

Statistical analysis. To process the quantitative data, mathematical statistics methods were used, including the Shapiro–Wilk test to verify the normality of the distribution, Independent Samples t-test to compare differences between groups, Paired Samples t-test to analyze intragroup progress, and Cohen's d

coefficient calculation to determine the practical significance of the impact of the MATHOS AI platform.

**The scientific novelty** of the dissertation lies in the fact that for the first time a quasi-experimental assessment of the intellectual tutor system based on AI (MATHOS AI) in teaching fractions among students in grades 5 of Almaty schools was carried out; the direct influence of AI feedback on the development of self-regulated learning (SRL) skills- planning, self-control, reflection; Ebbinghaus based on the theory of the forgetting curve was revealed For the first time, the pedagogical capabilities of a teacher in the context of remediation training (restoration of previously acquired knowledge) were empirically tested.

**Practical Significance of the Study.** The results of the study provide an empirical basis for the development of an evidence-based methodology for the introduction of ITS in general education schools in Kazakhstan. Diagnostic tools, pedagogical scenarios, and recommendations for teacher training are of direct practical use. The experience of Almaty schools can become a pilot model for other regions of Kazakhstan and CIS countries in Central Asia.











































2020) clearly show that Kazakhstan's average indicators of mathematical literacy are characterized by specific conceptual difficulties – fractions and proportions.

Kuandykova et al. (2023) and Zhumagazina et al. (2024) A recent study found that 60-70% of school teachers in Kazakhstan are unable to effectively use AI tools in the learning process-a mirror of the global trend described by Luckin and Holmes (2018). Another real problem is the lack of full-fledged AI systems in Kazakhstan in the Kazakh language: the leading AIS of the global market (MATHia, ALEKS, Khan Academy) work in English. Almaty can become a pilot platform for the introduction of AI tutors as the most developed educational center in Kazakhstan. For successful implementation, four conditions must be met: professional development of teachers, methodological support, cooperation with parents, and long-term planning.

The systematic theoretical analysis carried out in these two chapters allowed us to comprehensively recreate the theoretical and empirical prerequisites of the research problem in four interrelated areas. The first direction establishes that mastering fractions is not an accidental pedagogical difficulty, but a personal experience of the most complex epistemological leaps in the intellectual history of a person. The second direction shows that SRL is one of the strongest predictors of academic development, neuropsychological data prove the biological unpreparedness of 11-12-year-olds for full-fledged self-regulated learning and the Sweller CLT theory determines the biological need for external support. The third direction proves that modern information systems can offer exactly this advanced digital support: their four-component architecture, adaptive support mechanisms, instant feedback capabilities, and metacognitive control functions make up a comprehensive technological solution aimed at developing students' own skills. The fourth direction confirms the global experience – data on the effectiveness of Mathia, ALEKS, Khan Academy, Molenaar hybrid regulatory studies, and empirical data on anxiety reduction. But there are also acceptable limitations: excessive support, bypassing the system, and a gap in equality.

The most important conclusion: although the overall effectiveness of AI has been widely studied, its real role in fraction education-along with the development of SRL

– is not well understood, given the special post-Soviet education system and the cultural context of Central Asia. This gap is the theoretical foundation and practical significance of this dissertation.























To test the  $H_{1\beta}$  hypothesis, the MSLQ questionnaire was administered to both groups at post-test (end of week 4) to measure final levels of self-regulated learning and compare EG vs CG. The questionnaire was conducted for both groups simultaneously to ensure comparable conditions and time frames. This made it possible to statistically compare the changes in SRL between EG and CG using paired and independent t-tests.

























problem in principle: this effect is achieved without additional load on the teacher and changing the class schedule – the platform works as a 24/7 personalized tutor, which can adapt to the individual pace and difficulty profile of each student.









In conclusion, experimental verification and determination of the pedagogical and psychological impact of adaptive learning technology based on artificial intelligence (Mathos AI platform) on remediation training of 5th grade students of the 210th Lyceum in Almaty on the topic of fractions and self-regulated learning skills.

In the first chapter, the cognitive complexity of a fractional number was analyzed on three theoretical grounds: Kieren (1976) five semantic constructions determine the conceptual diversity of a fraction, Siegler et al. (2011) the integral theory of numerical development revealed the predictive value of fraction ownership for mathematical success ( $\beta = 0.37$ ,  $p < 0.001$ ), and the phenomenon of 'Whole Number Bias' (WNB) Ni & Zhou (2005) discovered the neurobiological roots of this barrier. Mathematical anxiety (Ashcraft, 2002; Lyons & Beilock, 2012) has been defined as an emotional barrier to mastering fractions.

In the second chapter, the three-phase cyclic Zimmerman model (2000, 2002) (forecast – execution – reflection) was designated as the main theoretical basis for self-regulated learning. Neuropsychological features of students aged 11-12 (incomplete maturation of the anterior cortex, limited working memory) determined the importance of purposeful formation of SRL skills at this age. Sweller's (1988) cognitive load theory theorized a mechanism by which MATHOS AI prevents working memory overload by using step-by-step instructions.

Key empirical findings. In the third chapter, the results of the quasi-experimental study were presented at three levels:

The first level is academic success: EG scored  $M = 78.6$  ( $SD = 7.9$ ) on the post-test and showed a statistically significantly higher result than  $M = 73.3$  ( $SD = 8.4$ ) on CG ( $t(48) = 2.30$ ,  $p = 0.026$ , Cohen's  $d = 0.65$ ). EG growth (+16.5 points) is 6.0 points higher than CG growth (+10.5 points). Hypothesis  $H_{1a}$  was confirmed.

The second level is a reallocation of academic achievement: the share of "low-level" students in EG has tripled from 36% to 12%; "high-level" has more than doubled from 12% to 28%. In CG, these changes remained insignificant (+4% and -8%). The



## 6. LIMITATIONS

Despite the significance of the results obtained, the study has a number of important limitations that should be taken into account when interpreting the data and generalizing to other contexts.

The sample size ( $N=50$ ) is relatively small. Although a posteriori power analysis confirmed that the power was sufficient to detect medium-sized effects ( $d=0.5$ ), a larger sample ( $N\geq 200$ ) would have provided more stable estimates. The study was conducted in one specialized school (lyceum) in Almaty among academically successful students with a higher initial level of training, greater motivation and more educated parents compared to typical general education schools. This limits generalization to rural schools, typical schools, and schools with different socio-economic status. A quasi-experimental design without randomization means that non-measurable variables cannot be completely excluded as alternative explanations for differences between groups, although the initial equivalence of the groups has been statistically confirmed.

The intervention lasted only 4 weeks, allowing short-term effects to be assessed according to Ebbinghaus' theory of forgetting, but leaving out questions about the long-term improvements. The study was conducted at the end of the school year, when students' motivation may be lower. The study included only the 5th grade (10-11 years old), so the results may not apply to other classes where cognitive development and motivational profiles differ significantly. Focusing on one mathematical topic (fractions) limits applicability to other mathematical topics.

Academic achievement was measured by a single test of 15 tasks, and self-directed learning was evaluated exclusively through self-report (MSLQ), which is subject to social desirability bias and recall bias. Although mathematical anxiety was theoretically significant and considered in the literature, it was not empirically measured in the study. It was a conscious choice to focus the main measurement efforts on academic achievement and self-regulated learning; measuring anxiety is recommended for future research using specialized tools.

Despite these limitations, the study demonstrates high internal validity in controlled aspects: the initial equivalence of the groups is statistically confirmed, the normality of the distribution is verified (Shapiro-Wilk,  $p > 0.05$ ), the reliability of the tools is adequate (Cronbach's  $\alpha = 0.84$ ), and the procedures are implemented in good faith. The results correspond to theoretical predictions and international meta-analyses of the effectiveness of intelligent learning systems. These limitations highlight the importance of replication studies with a larger and more diverse sample, with a longer follow-up period, multiple measurement methods, and in different educational contexts to strengthen the empirical base for implementing AI learning systems in Kazakhstan's education.



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### III БӨЛІМ. АНАЛИТИКАЛЫҚ ЕСЕПТЕР

9.  $\frac{3x}{8} \div \frac{5}{12} = \frac{7}{24}$

10.  $\frac{3x}{8} - \frac{5}{12} = \frac{7}{24}$

11. Бір санның  $\frac{5}{6}$  бөлігі екінші санның  $\frac{3}{4}$  бөлігіне тең. Екінші сан 48 болса, бірінші санды табыңыз.

12. Тік төртбұрыштың ұзындығы  $18\frac{1}{2}$  см. Ені ұзындығының бөлігі. Тік төртбұрыштың: енін; периметрін; ауданын табыңыз.

13. Үш санның қосындысы  $18\frac{1}{2}$ -ге тең. Бірінші сан  $-\frac{5}{6}$ . Екінші сан бірінші саннан  $2\frac{1}{3}$  -ге артық. Үшінші сан екінші саннан  $\frac{7}{12}$  -ге кем. Үш санды табыңыз.

### IV БӨЛІМ. ЖОҒАРЫ ДЕҢГЕЙЛІ ЕСЕПТЕР

14. Бөшкедегі судың: бірінші күні  $\frac{1}{3}$  бөлігі, екінші күні қалғанының  $\frac{2}{5}$  бөлігі, үшінші күні тағы 48 литрі пайдаланылды. Осыдан кейін бөшкеде бастапқы судың  $\frac{1}{6}$  бөлігі қалды. Бастапқыда бөшкеде неше литр су болған?

15. Бір жұмысшы жұмыстың: бірінші күні  $\frac{2}{9}$  бөлігін, екінші күні қалғанының  $\frac{1}{3}$  бөлігін орындады. Үшінші күні тағы 20 жұмыс орындағаннан кейін жұмыстың  $\frac{1}{4}$  бөлігі аяқталмай қалды. Барлық жұмыс көлемін табыңыз.

**MSLQ САУАЛНАМАСЫ – 5 ШКАЛА, 18 ПУНКТ**

*Motivated Strategies for Learning Questionnaire*

*(Pintrich et al., 1991 – 5-сынып оқушыларына бейімделген қазақша нұсқасы)*

**БӨЛШЕКТЕРДІ ОҚУ КЕЗІНДЕГІ ӨЗІН-ӨЗІ РЕТТЕУ  
САУАЛНАМАСЫ**

**Нұсқаулық**

Төмендегі сөйлемдерді оқып, өзіңе сәйкес жауапты белгіле. Сенің бөлшектерді оқу кезіндегі әрекеттерің мен ойлау жолдарың бағаланады.

1 = Мүлдем келіспеймін

4 = Келісемін

2 = Келіспеймін

5 = Толық келісемін

3 = Кейде солай

**1-БӨЛІМ. ЖОСПАРЛАУ (PLANNING)**

**1. Күрделі бөлшек есебін көргенде, оны шығару үшін қандай қадамдар керек екенін ойлаймын.**

☐ 1    ☐ 2    ☐ 3    ☐ 4    ☐ 5

**2. Есеп шығарғанда, маған қай тәсіл жақсы көмектесетінін таңдай аламын.**

☐ 1    ☐ 2    ☐ 3    ☐ 4    ☐ 5

**3. Жаңа тапсырманы бастамас бұрын, бұрын үйренген ережелерді еске түсіремін.**

☐ 1    ☐ 2    ☐ 3    ☐ 4    ☐ 5

**4. Мен бөлшектерді толық түсіну үшін қанша уақыт керек екенін алдын ала болжаймын.**

☐ 1    ☐ 2    ☐ 3    ☐ 4    ☐ 5

**5. Тапсырманы орындағанда қай жері қиын болуы мүмкін екенін алдын ала байқаймын.**

☐ 1    ☐ 2    ☐ 3    ☐ 4    ☐ 5

**6. Бөлшектерді оқығанда, өзіме “нені жақсы түсінуім керек?” деген сұрақ қоямын.**

☐ 1    ☐ 2    ☐ 3    ☐ 4    ☐ 5

## **2-БӨЛІМ. ОРЫНДАУ (PERFORMANCE)**

**7. Есеп шығару кезінде әр әрекетімнің дұрыс екенін тексеріп отырамын.**

☐ 1    ☐ 2    ☐ 3    ☐ 4    ☐ 5

**8. Егер жауабым түсініксіз болса, есепті басқа тәсілмен шығарып көремін.**

☐ 1    ☐ 2    ☐ 3    ☐ 4    ☐ 5

**9. Есеп шығарғанда, назарымды басқа нәрселерге аудармауға тырысамын.**

☐ 1    ☐ 2    ☐ 3    ☐ 4    ☐ 5

**10. Түсінбей қалған жерде тоқтап, қайта ойланып шығамын.**

☐ 1    ☐ 2    ☐ 3    ☐ 4    ☐ 5

**11. Күрделі тапсырмаларда бірден берілмей, соңына дейін ізденемін.**

☐ 1    ☐ 2    ☐ 3    ☐ 4    ☐ 5

**12. Есеп шығару кезінде өзіме “мен мұны не үшін істеп жатырмын?” деп сұрақ қоямын.**

☐ 1    ☐ 2    ☐ 3    ☐ 4    ☐ 5

## **3-БӨЛІМ. ӨЗІН-ӨЗІ ТАЛДАУ (SELF-REFLECTION)**

**13. Тапсырманы аяқтағаннан кейін, қай тәсіл жақсы көмектескенін ойлаймын.**

☐ 1    ☐ 2    ☐ 3    ☐ 4    ☐ 5

**14. Қате жіберсем, оның себебін түсінуге тырысамын.**

☐ 1    ☐ 2    ☐ 3    ☐ 4    ☐ 5

**15. Келесі тапсырманы жақсы орындай алу үшін жұмысымды қалай өзгерту керек екенін ойлаймын.**

☐ 1    ☐ 2    ☐ 3    ☐ 4    ☐ 5

**16. Бұрын үйренген тәсілдерді жаңа бөлшек есептерінде қолдана аламын.**

☐ 1    ☐ 2    ☐ 3    ☐ 4    ☐ 5

**17. Қай тақырыптарды жақсы түсінетінімді және қайсысы қиын екенін ажырата аламын.**

☐ 1    ☐ 2    ☐ 3    ☐ 4    ☐ 5

**18. Өз жұмысымды қарап шыққанда, келесі жолы нені жақсарту керек екенін байқаймын.**

☐ 1    ☐ 2    ☐ 3    ☐ 4    ☐ 5

## Appendix C. Lesson plan

| Сабақ кезеңі / Уақыты                                        | Педагогтің іс-әрекеті                                                                                                                                                                                               | Оқушының іс-әрекеті                                                                                                                                                    | ЖИ (Платформаның) қызметі мен рөлі                                                                                                                                    | Ресурстар және бағалау                                                                                                                 |
|--------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| <b>1. Мотивация және мәселе қою</b><br><br><i>(10 минут)</i> | <ul style="list-style-type: none"> <li>Проблемалық сұрақ қояды: <i>2/3-нің 4/5 бөлігін қалай табамыз? Ортақ бөлім керек пе?»</i></li> <li>Оқушыларды ЖИ ортасында өздігінен зерттеу жүргізуге бағыттады.</li> </ul> | <ul style="list-style-type: none"> <li>Сынып белсенділігіне қатысады, жұппен болжамдар жасайды.</li> <li>Ноутбук/планшет арқылы «MathosAI» жүйесіне кіреді.</li> </ul> | <ul style="list-style-type: none"> <li>Сұранысты қабылдауға дайын (Ready-state) интерфейсті көрсетеді.</li> <li>Пайдаланушының жеке профилін белсендіреді.</li> </ul> | <ul style="list-style-type: none"> <li>Планшеттер, интерактивті тақта.</li> <li>Бағалау: Диагностикалық алық (ынталандыру).</li> </ul> |
| <b>2. ЖИ-мен дербес зерттеу (Self-learning)</b>              | <ul style="list-style-type: none"> <li>Сыныпта фасилитатор болады.</li> </ul>                                                                                                                                       | <ul style="list-style-type: none"> <li>ЖИ-ге сұрақ қояды: <i>«Бөлшектерді қалай көбейтеді/бөледі?»</i></li> </ul>                                                      | <ul style="list-style-type: none"> <li><b>Сократтық коуч:</b> Дайын формуланы бермейді.</li> </ul>                                                                    | <ul style="list-style-type: none"> <li>«MathosAI» платформасы, жұмыс дәптері.</li> </ul>                                               |

| Сабақ кезеңі / Уақыты                                  | Педагогтің іс-әрекеті                                                                                                                                                      | Оқушының іс-әрекеті                                                                                                                                                                       | ЖИ (Платформаның) қызметі мен рөлі                                                                                                                                                     | Ресурстар және бағалау                                                                                                                             |
|--------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| (20 минут)                                             | <ul style="list-style-type: none"> <li>Мұғалімнің басқару панелі (Dashboard) арқылы әр оқушының ЖИ-мен диалогын және логикалық қадамдарын қадағалайды.</li> </ul>          | <ul style="list-style-type: none"> <li>ЖИ қойған жетектеуші сұрақтарға жауап береді.</li> <li>Ережені өздігінен тұжырымдап, дәптерге жазады.</li> </ul>                                   | <ul style="list-style-type: none"> <li>Бөлішті бөлу мысалында логикалық сұрақтар қояды.</li> <li>Оқушының жауап беру қарқынына бейімделеді.</li> </ul>                                 | <ul style="list-style-type: none"> <li>Бағалау: Қалыптастырушы (ЖИ аналитикасы).</li> </ul>                                                        |
| <b>3. Бекіту және STEM-практикум</b><br><br>(20 минут) | <ul style="list-style-type: none"> <li>Сыныпты 3 топқа бөледі.</li> <li><b>STEM тапсырмасы:</b> «Аспаздық рецептті масштабтау» (интернет тегі рецепт ингредиент</li> </ul> | <ul style="list-style-type: none"> <li>Топта есептеулер жүргізеді.</li> <li><b>Қатемен жұмыс:</b> Аралық нәтижелерді ЖИ-ге енгізіп, есептеу қадамдарының дұрыстығын тексереді.</li> </ul> | <ul style="list-style-type: none"> <li><b>Верификатор:</b> Оқушының шешімін талдайды.</li> <li>Қатені (мысалы, бөлшекті аударуды ұмыту) дайын жауапсыз, тұспалмен меңзейді.</li> </ul> | <ul style="list-style-type: none"> <li>Үлестірмелі материалдар (STEM карточкалары), планшеттер.</li> <li>Бағалау: Топтық өзара бағалау.</li> </ul> |

| Сабақ кезеңі / Уақыты                                       | Педагогтің іс-әрекеті                                                                                                                                                                      | Оқушының іс-әрекеті                                                                                                                                                                   | ЖИ (Платформаның) қызметі мен рөлі                                                                                                                                        | Ресурстар және бағалау                                                                                                                           |
|-------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                             | ттерін бөлшек сандарға көбейту/бөлу арқылы қайта есептеу).                                                                                                                                 |                                                                                                                                                                                       |                                                                                                                                                                           |                                                                                                                                                  |
| <p><b>4. Рефлексия және қорытынды</b></p> <p>(10 минут)</p> | <ul style="list-style-type: none"> <li>• Ережелерді бекітуді модерациялайды.</li> <li>• Диссертация үшін кері байланыс алады: «ЖИ сұрақтары ережені түсінуге қалай көмектесті?»</li> </ul> | <ul style="list-style-type: none"> <li>• Көбейту/бөлу алгоритмін сыныпқа тұжырымдайды.</li> <li>• Білім алудағы дербестігін бағалау үшін қысқаша Google-форманы толтырады.</li> </ul> | <ul style="list-style-type: none"> <li>• Мұғалімге есеп (Report) өткізеді: сыныптағы жиі кеткен қателер мен оқушылардың тақырыпты меңгеру деңгейін жинақтайды.</li> </ul> | <ul style="list-style-type: none"> <li>• Google-форма / Сауалнама парақшалары.</li> <li>• Бағалау: Жиынтық бағалау, өзін-өзі бағалау.</li> </ul> |

| <b>Сабақ<br/>кезеңі /<br/>Уақыты</b> | <b>Педагогті<br/>ң іс-<br/>әрекеті</b>                                 | <b>Оқушының<br/>іс-әрекеті</b> | <b>ЖИ<br/>(Платформа<br/>ның)<br/>қызметі мен<br/>рөлі</b> | <b>Ресурстар<br/>және<br/>бағалау</b> |
|--------------------------------------|------------------------------------------------------------------------|--------------------------------|------------------------------------------------------------|---------------------------------------|
|                                      | <ul style="list-style-type: none"> <li>• Балл қояды (1–10).</li> </ul> |                                |                                                            |                                       |