Vol.04 No.01 (2026)

ENHANCING MATHEMATICS LEARNING FOR 5TH-GRADE STUDENTS:

Rabia Rashid
PhD Scholar, Faculty of Social Sciences, Northern University, Nowshera
rabia.heco@gmail.com
Professor, Faculty of Social Sciences, Northern University, Nowshera
jamil.bajwa@northern.

This paper examines optimization of digital learning programs to work with 5th -grade students in Islamabad as a factor in enhancing learning in mathematics. Although digital tools in education are increasingly embraced, research on their effectiveness in developing countries such as Pakistan, especially in the primary level, is not robust. The study relies on both quantitative and qualitative methodologies; thus, a quantitative quasi-experimental study design is used with interviews analyzing teacher opinions. The experimental condition (that used digital applications) was significantly higher in post-test scores (M = 26.60, SD = 5.30) than the control condition (M = 21.60, SD = 5.10), and the mean difference on post-test scores was significant (12.09, p < .001). The teachers said that digital tools improved student engagement and understanding of concepts and problem-solving abilities. Nevertheless, the following issues were raised: poor teacher preparation, deficiencies of facilities and school curricula misfit. The connotation of the study is that mathematics learning can be extremely improved with the help of digital application when used with conventional teaching approaches. It will be recommended to train teachers, develop infrastructure, align curriculum and involve parents to maximize the benefits of the digital learning tools.

Keywords:
Online learning software, mathematics education, 5th -grade students, blended learning, training of teachers, infrastructure, curriculum mapping.

Introduction

The uptake of digital learning apps in primary education has received immense interest because of its ability to improve student interactivity, understanding of concepts, and academic success. Conventional modes of teaching, commonly based on rote learning, cannot support different styles of learning, and they do not offer an interactive learning experience. Digital applications provide visual, gamified and interactive content where students can understand abstract areas of mathematics better.

Digital tools can also be used to fill the learning gaps that exist in developing nations such as Pakistan, where educational resources are usually scarce, with learning being made equally accessible to quality education. Nevertheless, there is a lack of research into how well these tools can be implemented in these settings, especially in primary schools. This paper will consider how digital applications can affect 5th-grade mathematics students in Islamabad, the role of digital apps, the level of student involvement, and related implementation issues. By bridging the gap in the empirical evidence base, the research will contribute to actionable information to educators and policymakers on how to make the most of digital tools in primary education.

Problem Statement

Although the application of digital learning in classrooms is on the rise, few empirical studies have been conducted on how these technologies can enhance the mathematics performance of primary students in Islamabad. In addition, teacher training, access to technology, and curriculum alignment are some of the challenges that put their successful implementation at a disadvantage. This research project aims to fill this gap by considering the effect of using digital applications on mathematics performance of students and determining major barriers to their successful application.

Objectives

1. To assess the effect of digital educational applications on 5th-grade mathematics students' academic performance.
2. To determine important variables that determine the success of digital learning applications.

3. To compare the traditional approach of teaching with the introduction of teaching with digital learning tools.

Hypotheses

H1: Digital learning tools can achieve great student engagement and understanding of concepts in 5th-grade mathematics significantly better than traditional teaching applications.

H2: The success of digital use is related to educator training, technological resources, academic alignment, and engagement of parents.

H3: Digital educational applications are applied by students to attain a significantly better result in post-tests compared to students taught in traditional ways.

Review of Literature

Mathematics education during the primary years lays the foundation for children's intellectual growth, academic progress, and future life opportunities. Competencies such as counting, pattern recognition, measurement, and quantitative reasoning support not only achievement in mathematics but also overall academic development (Dieuwer ten Braak, 2021). Beyond academic achievement, mathematics contributes significantly to the development of higher-order thinking abilities. According to Aghaei and Ahmadi (2017), mathematics education extends far beyond numerical computation by fostering logical reasoning, problem-solving skills, and critical thinking. Activities involving estimation, measurement, pattern recognition, and problem-solving help students develop a deeper understanding of mathematical ideas. This need for active engagement has become increasingly relevant as digital technologies continue to transform educational environments. Over the past decade, digital educational applications (DEAs) have become an important feature of mathematics instruction. The adoption of digital educational apps in primary schools has been a major issue of discussion over recent years, and scholars have examined the possible opportunities of digital educational apps to increase student engagement, conceptual knowledge, and academic performance. This part is a literature review of the application of digital tools in education, in relation to their effects on learning mathematics, the issues related to the use of the tools, and the factors that can determine their effectiveness.

1. The Role of Digital Tools in Enhancing Mathematics Learning

Digital education apps have been found to enhance student learning experiences in mathematics, where the abstract concepts become more explicable and involve all students. In a large-scale meta-analysis of 36 intervention studies, Kim, Gilbert, Yu, and Gale (2021) reported an overall positive effect of educational applications on children's mathematics and literacy achievement (+0.31 SD). However, the authors also emphasized that outcomes vary depending on factors such as application design, instructional integration, and learner characteristics. Similarly, Verbruggen, Depaepe, and Torbeyns (2021) concluded that educational technology can strengthen early mathematical competencies when implemented under supportive instructional conditions and accompanied by effective teacher guidance. Research conducted in classroom settings also points to positive academic outcomes associated with digital applications. Barrientos (2021), using the Technological Pedagogical Content Knowledge (TPACK) framework, found that students progressed from "Developing" to "Proficient" and "Advanced" levels after using mathematics applications. Similarly, Ulun (2023) reported that fourth-grade students learning through Khan Academy outperformed peers using an alternative digital platform. The success of such applications is often attributed to features such as adaptive learning, immediate feedback, and self-paced instruction. These findings align with the observations of Engelbrecht and Borba (2023), who noted a growing shift toward the use of digital tools, artificial intelligence, and interactive platforms to personalize mathematics learning and encourage deeper conceptual understanding.

The motivational value of digitally based tools has also been mentioned in studies. Jarrah et al. (2022) discovered that gamified learning systems, including ABACUS, were effective in enhancing students' knowledge about fractions through increased engagement in the learning process and by making it enjoyable. Gideon, Haruna, and Umar M. A. (2021) examined the use of the Prodigy Math game among primary school students in Nigeria and found that learners who used the application developed significantly more positive attitudes toward mathematics than those in a control group. These results align with those of Ristic et al. (2023), who revealed that academic failures among students with adaptive e-learning tools were higher as compared to those in a conventional classroom. The digital applications can enable students to learn slowly at their own pace thus potentially resulting in higher performance and retention of mathematical concepts.

2. Hurdles in the Digital Implementation

Although there can be a significant advantage to the use of digital educational applications, there is a risk of this advantage failing to be implemented due to a number of issues. Teacher support consistently emerges as one of the most influential factors in successful technology integration. Alrajeh and Shindel (2020) found that instructional support was the strongest predictor of student engagement in mathematics classrooms. Similarly, Ristić et al. (2023) demonstrated that adaptive e-learning systems designed for individual learning needs improved student motivation, satisfaction, and learning effectiveness. The importance of understanding learner goals, needs, and emotional experiences when developing digital resources is stressed by Weinhandl et al. (2024). Collectively, these studies suggest that technology is most effective when teachers actively facilitate learning rather than simply introducing digital tools into the classroom.

A major challenge is also the access to technology and infrastructure constraints. Waqar, Muhammad, and Anis (2024) documented substantial disparities between urban and rural areas of Pakistan in terms of broadband connectivity, device ownership, and digital literacy. Malik (2024) similarly highlighted the challenges experienced during the transition to online learning, including unreliable internet services, limited access to devices, insufficient digital skills, and inadequate institutional support.

3. Curriculum Congruity and Content Formulation

The compatibility with the curriculum is another major aspect that predetermines the efficacy of digital educational applications. Jarrah et al. (2022) noted that digital tools should be coordinated with the national learning objectives and textbooks in order to empower the national learning outcomes to be consistent. But Weinhandl et al. (2024) concluded that the coverage of the curriculum can have some gaps, and not all topics are addressed on digital applications properly. This can lead to inconsistencies in learning and hinder students' ability to achieve the desired learning outcomes.

In order to solve this problem, Ristić et al. (2023) suggested a partnership between educational establishments and EdTech developers to develop digital content on a local level that would focus on the needs of students in various areas. This strategy will make digital tools applicable and useful towards the learning goals of the curriculum.

4. The Blended Learning Approach

It has been demonstrated that a blended learning, a learning model that involves a combination of digital tools with more traditional teaching techniques, is most effective to increase student learning outcomes. Horn and Staker (2014) described blended learning as an instructional model in which students alternate between teacher-led activities and digital learning experiences. Research conducted by Halverson et al. (2017) and Kiger, Herro, and

Prunty (2012) demonstrated that blended environments can increase student engagement and provide additional opportunities for reviewing complex concepts through videos, applications, and other digital resources. Similarly, Zacharia, Olympiou, and Papaevripidou (2008) found that combining virtual manipulatives with hands-on instruction was more effective for teaching abstract concepts than relying solely on traditional methods. Evidence from Pakistan also supports this approach. Ali, Ullah, and Habib (2022) reported higher achievement among Grade 6 students who received video-supported blended instruction, while Ahmed and Anwar (2023) found positive effects of blended learning on Grade 5 mathematics achievement in Punjab schools. Engelbrecht and Borba (2023) assured that a balanced approach towards digital learning is essential as digital tools can improve student engagement and conceptual knowledge; however, they are not supposed to be applied independently. The teachers are very important in helping to support digital learning and making sure that the students are being given the support they require so as to reach their learning goals.

5. Parental Involvement and Socioeconomic Factors

The socioeconomic factors and parental involvement are also greatly considered as determinants in effectiveness of digital educational applications. Teoh et al. (2022) found that parental involvement positively influenced students' learning outcomes during technology-supported mathematics instruction. This effect was particularly evident in rural communities, where teachers frequently relied on communication platforms such as WhatsApp to engage families in the learning process. Joshi, Khatiwada, & Pokhrel (2024) identified barriers to access to digital learning resources such as a shortage of digital devices in the household and lack of internet connectivity as being common in students whose families have low income. This is capable of reducing their access to digital tools and amplifying the pre-existing educational disparities. To address these barriers, Afzal, Khan, Daud, Ahmad, and Butt (2023) recommended investments in affordable devices, improved connectivity, digital literacy initiatives, and stronger collaboration among governments, educational institutions, and private-sector organizations. Malik (2024) also suggested these options to mitigate these issues, such as low-cost or free access to digital devices among low-income students. Moreover, Weinhandl et al. (2024) recommended that colleges ought to collaborate with the parents in order to increase their awareness of the significance of digital learning as well as give them the support needed to help their children utilize the digital tools to their advantage.

6. Theoretical Frameworks Supporting Digital Learning

The growing use of digital educational applications can also be understood through several established theoretical perspectives. Constructivist theory views learning as an active process in which learners build knowledge through exploration, interaction, and experience. The technology-assisted learning minimizes the cognitive load, which display information in a structured and interactive way and enable students to master complex problems in mathematics (Hanggara, Sa'dijah, & Qohar, 2023). This perspective aligns closely with many interactive digital learning environments. Behaviorism offers another explanation by emphasizing reinforcement, feedback, and reward systems that shape learning behavior, making it particularly relevant to game-based applications (Holt, 2023). Cognitive Load Theory highlights the importance of presenting information in ways that reduce unnecessary mental effort and support effective learning (Centre for Education Statistics and Evaluation, 2017). The Technology Acceptance Model suggests that technology adoption depends largely on users' perceptions of usefulness, ease of use, and social support (Fuchs, 2022). Meanwhile, the SAMR model provides a framework for understanding how technology can evolve from merely substituting traditional methods to transforming learning experiences altogether (Blundell & Mukherjee, 2022).

The literature points to the possibility of digital education application to positively affect mathematics learning experiences by increasing student engagement and conceptual and problem-solving abilities. But in order to implement these tools effectively, challenges like training of teachers, infrastructure development and aligning curriculum must be addressed. A blended learning model that is a mixture of digital technology and conventional instructional practices stands out as the most effective approach towards maximising the learning outcome of students. Also, the role of parental involvement and socioeconomic factors is crucial to the effectiveness of digital learning tools and this consideration requires specific interventions to provide equal access to digital learning.

Research Methodology

Research Design

This research used an explanatory sequential mixed research design, which entails two stages:

Phase 1 (Quantitative): A quasi-experimental design is applied to compare the academic performance of the students who are taught with the help of digital applications (experimental group) and those taught with the usage of traditional methods (control group).

Phase 2 (Qualitative): The interviews were organized with the teachers in order to understand the challenges and the benefits of using digital tools in the classroom.

This design enabled the researcher to gather and analyze quantitative data to determine the effect of digital applications on student performance and then with the qualitative data to describe the results and explain the factors that lie behind the effectiveness of digital tools.

Population and Sample

Population: The population of the study was all the 5th grade mathematics students and teachers in the Model schools of the Federal Directorate of Education (FDE) in Islamabad.

Sample: A sample of 70 students (35 in experimental group and 35 in control group) was picked out of Islamabad Model School, G-11/1 through cluster sampling. The reason that this method was selected is that the way allows selection of groups (classes) of intact populations and not individual students and therefore the groups are naturally formed and representative of the population.

Sample of Teachers: A sample of 5 mathematics teachers was chosen based on criterion sampling, but they had to have experience in teaching mathematics using both the traditional and digital means. This enabled the generation of different attitudes towards the use of digital tools in the classroom.

Research Tools Development

The study employed the two predominant research instruments:

- **Achievement Test**: To assess achievement of students in mathematics a multiple-choice evaluative test was created. The test was grounded on curriculum 5th-grade mathematics curriculum. It included 50 multiple-choice questions consisting fractions, decimals, and percentages. These areas were identified as it is core to mathematics education and students frequently struggle with them. The questions had easy, medium and challenging difficulty level to assess the understanding of the students completely.
- **Structured Interview Guide**: A set of 20 open-ended questions were created to learn more about the experience of teachers regarding the usage of digital applications. The questions were based on the perceived usefulness of digital tools towards enhancing student learning and engagement, challenges in implementation, recommendations to improve pedagogical strategies by using digital tools.

Data Collection Procedures

The data collection was conducted in three months and performed in the following steps:

Pre-Test: Experimental group and control group assigned a pre-test to understand their baseline mathematics achievement levels.

Treatment: Digital applications were used to teach the experimental group in six weeks. The computer-based materials were interactive videos, a gamified activity, and PowerPoint slides. The control group went on with being taught through the traditional means i.e. lectures and explanation on whiteboard.

Post-Test: Both groups then had a post-test on their mathematics achievement after the six-week intervention. Post-test was the same format and level of the pre-test to make the results comparable.

Teacher Interviews

All five mathematics teachers were interviewed, after which structured interviews offered the chance to collect qualitative data on experiences with digital tools. The time of each interview ranged between 45 and 60 minutes, which was voice recorded on mobile to be transcribed and analysed.

Validation of Instruments

In order to guarantee research instruments validity and reliability the following steps were undertaken:

Achievement Test Validation

- **Content Validity**: The test was checked by the five subject experts which consisted of curriculum specialists and the experienced mathematics teacher. They examined the test in terms of clarity, relevance, and in congruence with the 5^{th} -grade mathematics curriculum.
- **Pilot Testing**: A sample of 35 students in the same school took the test, and possible ambiguities in the questions or any other problems of the test were identified.
- **Item Analysis**: Based on the pilot test, the test items were adjusted using statistical techniques including difficulty index and discrimination index. Those that had a difficulty index ranging between 0.30 and 0.70 and higher discrimination index of 0.20 were retained.
- **Reliability**: Cronbachs Alpha was used to determine the reliability of the test and it gave the values 0.828 (fractions section), 0.752 (decimals section) and 0.720 (percentages section) and these were good internal consistency.

Validation of Structured Interview

- **Review by Experts**: Two educational experts reviewed the interview guide to make sure that the questions were understandable, pertinent and relevant to the objectives of the research.
- **Pilot Testing:** The interview guide was pilot tested on two teachers in order to determine whether the questions have any ambiguities or problems.
- Refinement: The interview guide has been based on the feedback of the pilot test and was refined to enhance sense making and relevance.
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Results

Descriptive Statistics

Table 1: *Comparison of Pre-Test and Post-Test Scores*

Group	Test	N	Mean	Std. Deviation
Experimental	Pre-Test	35	14.51	3.88
Comparison	Pre-Test	35	19.26	4.10
Experimental	Post-Test	35	26.60	5.30

Comparison	Post-Test	35	21.60	5.10

The experimental group had a lower mean pre-test score (M = 14.51, SD = 3.88) compared to the control group (M = 19.26, SD = 4.10). Nevertheless, post-test scores (M = 26.60, SD = 5.30) of the experimental group (M = 21.60, SD = 5.10) significantly improved after the intervention. This means that the adoption of the digital applications had a beneficial effect on students performance.

Table 2: *Independent Samples T-Test Results Comparing Post test scores of Experimental and Comparison Groups*

Test	t-value	df	Sig. p (2-tailed)	Mean Difference	Std. Error Difference	Cohen's d (Effect size)
Post test	-4.020	68	.001	-5.000	1.243	0.96 (large effect)

According to the results of an independent t-test, the difference between the post-test scores of the experimental and control groups is statistically significant (t = -4.020, p < .001). It implies that the group of ready to use the digital applications as an experiment performed much better than the control group.

Table 3: *Paired Sample t-Test Results: Comparing Pre-Test Post test Scores of Experimental Group*

Test	Mean Difference	Std. Deviation	t-value	df	Sig. (2-tailed)
Pretest - Posttest	-12.09	2.82	-25.338	34	.000

The experimental group paired t-test showed that the weighted mean increased significantly (M = 26.60) compared to the pre-test (M = 14.51) and the difference was very significant t (34) = -25.338, p = 0.001. This means that there is a high impact of the intervention on performance enhancement.

Table 4: *Paired Samples T-Test Results: Comparing Pre-Test post Test Scores of Comparison Group*

Test	Mean Difference	Std. Deviation	t-value	df	Sig. (2-tailed)
Pretest - Posttest	-2.34	4.98	-2.785	34	.009

The comparison group also exhibits a statistically significant improvement in scores from pre-test (M = 19.26) to post-test (M = 21.60), t(34) = -2.785, p = .009. However, the mean increase (2.34 points) was significantly smaller compared to the experimental group.

Qualitative Analysis

Table 4: *Thematic Analysis of Teacher Interviews*

Theme	Key Responses
Enhanced Student Engagement	"Students are more engaged and interested in learning with digital tools."
Improved Conceptual Understanding	"Digital applications help students grasp abstract concepts more easily."
Challenges in Implementation	"Lack of training and infrastructure are major barriers to using digital tools."
Blended Learning Approach	"Combining digital tools with traditional methods is the most effective strategy."

According to teachers, digital applications made students more engaged and conceptually understanding. Nevertheless, issues like a lack of training and infrastructure were also mentioned. Teachers stressed the significance of a blended approach of learning, involving the use of digital tools alongside conventional ones.

Discussion

The research results are very much in line with the objectives and hypotheses, and they provided priceless information on the effectiveness of digital educational applications in

improving the learning of mathematics among 5 th -grade students. The initial aim of the study was to evaluate the impact of digital uses on academic performance. The quantitative outcomes evidently show that, those students who resorted to the use of digital tools in the experimental group tended to score much higher (M = 26.60, SD = 5.30) than in the control group (M = 21.60, SD = 5.10) with the difference in to the mean increase of 12.09 points ($p < .001$). This is in favor of Hypothesis H2 that asserted that students who used digital applications would have a better performance compared to students who were taught using traditional methods. The results align with constructivist learning theory, which emphasizes active student engagement in the learning process (Hanggara, Sa'dijah, & Qohar, 2023). Digital applications facilitate visualization and provide interactive learning experiences, which align with cognitive load theory by reducing extraneous cognitive load and enhancing meaningful learning (Centre for Education Statistics and Evaluation, 2017). The results are consistent with the works of Ristić et al. (2023), who concluded that adaptive e-learning tools are greatly beneficial in improving academic performance through personalization of learning experiences.

The second aim was on determining the critical elements that contribute to the success of digital applications. Teacher interview qualitative data indicated both advantages and issues. There was reported increased engagement among the students and conceptual understanding, which corresponds to Hypothesis H1. As an example, one of the teachers mentioned, "Digital applications facilitate easier understanding of abstract concepts among the students. This is in line with Hanggara et al. (2023), who suggest that learning becomes more meaningful with fewer extraneous cognitive loads brought about by digital tools. Nevertheless, other major barriers raised by teachers were lack of training, constraints in infrastructures, and mismatch of curricula. These results highlight the need to pay attention to these aspects to make the most of digital tools in line with what Malik (2024) has stressed. However, resistance from senior teachers was also noted. Respondent 5 reported that "mostly the senior teachers are avoiding and hesitant to learn and adopt technology," highlighting the importance of structured teacher training programs, as emphasized by Fuchs (2022).

The third objective was to contrast the learning approaches in traditional education and the use of digital tools. The findings indicate that an integrated modality of blended learning between the use of digital applications and conventional tools is best. This was the most suggested strategy, particularly among teachers, who kept saying, "The best strategy is the integration of digital technologies with traditional ones. This includes constructivist learning theory that focuses on student active participation and scaffolding (Engelbrecht and Borba, 2023).

To sum up, the results of the research confirm all three hypotheses and emphasize the transformative potential of digital applications in mathematics education. Nevertheless, implementation needs to be successful, and it is essential to tackle several challenges like training of teachers, developing infrastructure, and aligning the curriculum. The recommendations align with Jarrah et al. (2022) who emphasize the need of systemic guidance toward integrating technology in education.

Conclusions

The results of this paper confirm that online learning resources can considerably improve the learning experience of mathematics students in 5th grade. The experimental group, which operated with the use of digital instruments, displayed a significant increase in the post-test performance in comparison to the control one, showing that digital tools can be successfully used to enhance academic performance. Letting go of the digital tools also

helped in increasing student engagement, conceptuality, and problem-solving skills, according to teachers.

Nevertheless, the research also shows that there are a number of challenges which must be overcome in order to implement digital applications successfully. These are related to poor training of teachers, infrastructure and curriculum mismatch. Moreover, parental participation and socioeconomic aspects are important issues, which influence the efficacy of digital learning resources.

In order to fully utilize the advantages of digital educational applications, a blended learning strategy which merges digital tools with the conventional educative strategies should be adopted. This strategy will ensure that students will get the best of both worlds, as the digital tools provide them with the interactivity and engagement, whereas traditional teachin will help them and encourage learning.

Recommendations

On the premise of having developed this research, the researcher would like to suggest that the next recommendations could help improve the effectiveness of digital educational applications in the 5th-grade mathematics education:

1. Training and development of teachers

- How does this program assist teachers in evolving professionally?
- Carry out periodic training of teachers to enhance their digital literacy and pedagogical skills in the use of educational applications.
- Reward teachers who undertake higher education in the area of digital pedagogy (e.g., through certifications, salary raises).
- Existing tech-savvy teachers should be allowed to mentor others in implementing digital technologies in lesson delivery well.

2. Technological and Infrastructure Support.

- Make sure that all classrooms have working digital devices (e.g., tablets, smartboards, projectors).
- Ensure schools have better internet access to avoid disruption of online education.
- Create technology-wide maintenance plan to have the operationality of digital tools in the school.

3. Curriculum Consistency and Content Constructing.

- Coordinate with curriculum developers to make sure that digital applications are in tune with national learning objectives (SLOS), as well as textbooks.
- Develop regionalized online materials to fit the individual academic requirement of students in various locations.
- Promote the cooperation between schools and EdTech creators to refine and update online content, and by making a regular update.

4. Blended Learning Approach

- Adopt a hybrid design that incorporates both the conventional and online teaching practices in order to optimize learning results.
- Design developed lesson plans integrating instructor-based and computer-based learning in a strategic way.
- Offer educators the rules as to how to strike a balance between technology application and traditional methods of teaching.

5. Parental awareness and involvement.

- Parent awareness campaigns should be conducted about the significance of digital learning and their involvement in facilitating the same at home.

- Give basic rules of the game to parents concerning the way to help their kids to use digital tools successfully.
- Establish a feedback mechanism through which parents can communicate their difficulties and propose some ways to improve them.

6. Addressing Socioeconomic Barriers

- Give students with low-income background access to digital devices at low costs or subsidized.
- Collaborate with nongovernmental organizations and government initiatives to finance online education in needy communities.
- Launch community learning centers where schools have minimal or no access to digital tools can be utilized to enhance technology-driven learning by students.

7. Monitoring and Evaluation

- Set up a system of continuous evaluation in order to determine the effect of digital applications on student performance.
- Regular evaluation and consultation with teachers and students on digital teaching plans.
- Take advantage of digital application data analytics to evaluate students and determine areas requiring improvement.
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