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The Use of Intelligent Tutoring Systems in Primary School Mathematics Education: A Systematic Literature Review

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Abstract

This study aims to establish a framework for the use of Intelligent Tutoring System (ITS) in primary school mathematics education based on the existing literature and to reveal its role in the learning process. To this end, a systematic literature review was conducted. Following the PRISMA approach, a total of 24 articles published between 2005 and 2025 in the WoS, Scopus, EBSCOhost, and ERIC databases were analysed. The results indicate that the use of ITS in primary school mathematics education predominantly focuses on the Numbers and Operations learning domain. It was determined that a majority of the studies were conducted using quantitative and design based research designs. The results demonstrate that the integration of ITS enhances students' academic achievement, problem-solving skills, and learning motivation. Furthermore, individualized, and adaptive learning opportunities were identified as the most significant advantages of use of ITS in primary school mathematics education. However, some of the studies reported that the competitive features embedded in the system occasionally led to decreased student motivation. Additionally, the results suggest that ITS contribute to reducing teachers' workload.

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Keywords: Intelligent Tutoring Systems, Mathematics Education, Primary School Students, Systematic Literature Review.

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Introduction

The changing learning needs of the digital age increase the use of artificial intelligence. The different learning pace, styles and interest areas of students has increased the need for individualized learning and artificial intelligence has come to the fore as a technology which produces string solutions for this need (Isidori et al., 2024; Salido et al., 2024). A more individualized learning environment can be provided by artificial intelligence technologies to students by analysing students' data, however the learning process can be made more interactive and accessible through feedback (Suttrisno and Yulia, 2024; Zhang and Arslan, 2021).

One of the widely used applications of artificial intelligence in education is Intelligent Tutoring Systems (ITS). Intelligent Tutoring Systems are defined as computer programs which provide individualized learning by modelling students' psychological states (Ma et al., 2014). These systems serve as a teacher which knows what they teach, who they teach and how they teach through the use of artificial intelligence techniques (Nwana, 1990). ITS are designed to meet the individualized learning needs of students and are intended for situations where they apply their knowledge, learn from mistakes and by structuring information (Murray, 1998). ITS, which are also referred to as knowledge based teachers, bring automated teaching closer to an ideal level, by incorporating content, learning process and computational models (knowledge bases) of the learning state of the student and by more closely simulating realistic situations (Wenger, 1987). When students engage in educational activities through ITS, they can receive individualized support based on various factors such as skill level, content knowledge, help-seeking behaviour, and self-regulation. This makes the learning process both more productive and more engaging (Kooken et al., 2021). Studies show that use of ITS produces greater success compared to teaching large groups under the leadership of the teacher, computed based teaching without ITS and textbooks or workbooks (Ma et al., 2014).

Intelligent Tutoring Systems have been developed in various disciplines to help students acquire cognitive and metacognitive information unique to the subject matter (Ma et al., 2014). One of these areas is mathematics. For instance, Lu (2005) has developed an ITS called InfoMap with the "Finding Nemo" theme in his study to teach arithmetic to primary school students, with the belief that enriching educational games with ITS will support students to learn in a more effective manner. Sarrafzadeh et al. (2008) adapted teaching strategies by perceiving the emotions and biological signals of students during learning mathematics with the Easy with Eve system they have developed. Keleş et al. (2009) have developed a system called "ZOSMAT" which can be used both in individual learning and in classroom environment under the guidance of the teacher. Similarly, Jaques et al. (2013) introduced a web-based algebra ITS called PAT2Math. This system, which has been developed with Java teaches linear and second degree equations and can be used in devices with internet connection. In addition, Özyurt et al.'s UZWEBMAT study provides qualitative findings on students' individual learning experiences and mathematical discovery processes in the probability unit.

According to the studies, the use of Intelligent Tutoring Systems (ITS) in mathematics education develops students' problem solving skills (Çetin, 2022), supports their reasoning skills (Paneque et al., 2016) and increases students' success in subjects such as rational numbers which are difficult to learn (Bush, 2021; Chu et al., 2021). In addition, it was shown that the use of ITS has positive effects on students' success and motivation in mathematics (Zafari et al., 2022; Moltudal et al., 2020; Annus and Kmet, 2024; Özyurt et al., 2014; Keleş, 2007; Aguilar et al., 2011; Rau et al., 2014). Additionally, students evaluate the use of ITS in mathematics education as an accessible, engaging and beneficial learning tool as well (Shih et al., 2023).

The use of Intelligent Tutoring Systems (ITS) in mathematics education affects primary school students' success in mathematics positively as well. Chen (2025) states that the use of ITS increases the performance of students as well as having positive effects on the interaction between students. Similarly, Pathaia et al. (2025) have reported that the dramatized and adaptable approach which they suggest for learning and evaluation of mathematical concepts at the primary school level both improves learning outcomes and increase the participation of students. In addition, Lin and Yang's study (2021) concluded that the self-organizing learning models which is supported by multi scaffolding provides higher student performance compared to traditional teaching models.

There are various literature reviews which aim at presenting the empirical evidence related to the use of Intelligent Tutoring Systems (ITS) in mathematics education in a holistic manner. When these studies are analysed, it is seen that two systematic compilations which directly deal with the use of ITS in mathematics education come to the fore. Niño-Rojas et al. (2024) analysed 43 studies published between 2012 and 2022 to identify trends related to the use of ITS in mathematics education in higher education. Similarly, in Son's study (2024) studies published between 2003 and 2023 were analysed on the basis of the SAMR model (Substitution, Augmentation, Modification, Redefinition) to determine how ITS are positioned in mathematics education and at which SAMR levels they are used in different educational stages. Although the years dealt with in these studies cover a long time period, the educational levels they focus on are different. While Niño-Rojas et al. (2024) have analysed the current state of the use of ITS in mathematics education in higher education institutions, Son (2024) has analysed the distribution of SAMR (Substitution, Augmentation, Modification, Redefinition) states to educational stages. In this respect, it was seen that the systematic literature reviews which were carried out do not involve the use of ITS in primary school mathematics education.

It is known that Intelligent Tutoring Systems (ITS) are in particular widely used in mathematics education in primary school mathematics education (Son, 2024). However, the number of studies which analyse to what extent and how ITS are applied at this level are limited. This study aims to fill the existing gap in the literature by identifying the current state, opportunities, and challenges regarding the use of Intelligent Tutoring Systems in primary school mathematics education, thereby offering original contributions to the field. The findings are expected both to help teachers use ITS more effectively from a pedagogical perspective and guide future instructional design practices. In this context, the study aims to establish a framework for the use of Intelligent Tutoring System in primary school mathematics education based on existing literature and to reveal its role in the learning process. The research questions are as follows:

1) In the literature on primary school mathematics education, how is the use of ITS distributed according to:
   a) mathematics learning domains,
   b) research methods,
   c) research findings?
2) In the literature on primary school mathematics education, regarding the use of ITS:
   a) what opportunities,
   b) what challenges have been identified?
3) In the literature on primary school mathematics education, how have the effects of the use of ITS on students and teachers been presented?

Method

In this study, a systematic literature review was carried out on the use of Intelligent Tutoring Systems in primary school mathematics education. The systematic review method was chosen as it aims to collect evidence based on explicitly defined eligibility criteria to answer the research question, provides a replicable methodology, and ensures that the studies included in the research are selected through systematic procedures, thereby enabling the acquisition of reliable findings and conclusions (Chandler et al., 2019). In this respect, this study analysed research articles published between 2005 and 2025. The reporting of these studies were prepared with PRISMA (The Preferred Reporting Items for Systematic Reviews and Meta-analysis) flow chart developed by Moher et al. (2009). This diagram consists of four stages: Identification, Screening, Eligibility, and Inclusion. Figure 1 presents the literature search and review process based on the PRISMA framework.

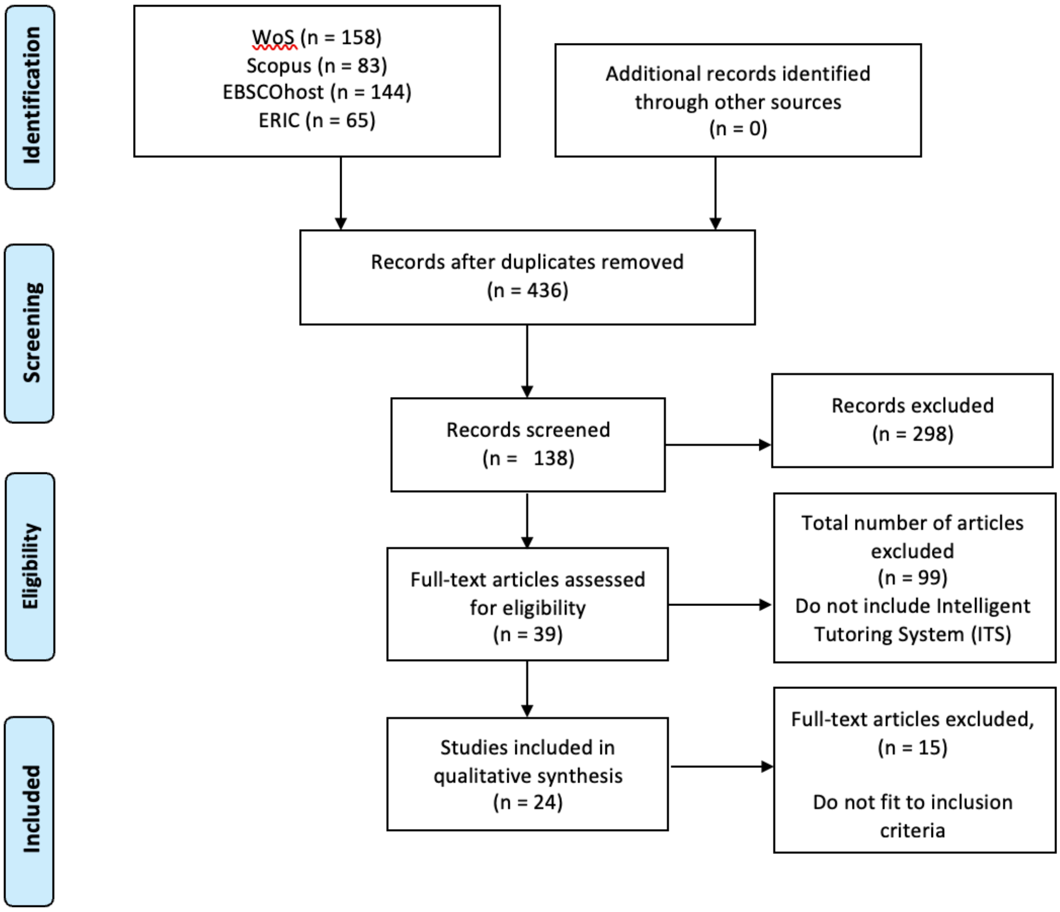

Figure 1. PRISMA flow diagram

Systematic Review Process

Identification

The Identification stage of the PRISMA process was conducted using the WoS, Scopus, EBSCOhost, and ERIC databases. Specific search terms were established to identify studies aligned with the aim of this research. Synonyms and related terms were expanded using Boolean operators to retrieve a broader range of studies. The search terms were as follows: ((“artificial intelligence”) OR (“machine intelligence”) OR (“intelligent support”) OR (“personal tutor”) OR (“expert system”) OR (“intelligent system”) OR (“intelligent tutor”) OR (“intelligent tutorial system”) OR (“adaptive learning”)) AND ((“Math”) OR (“Maths”) OR (“Mathematics”) OR (“Mathematical”) OR (“Math education”) OR (“Mathematics education”) OR (“Mathematical sciences”) OR (“learning of mathematics”) OR (“Mathematics teaching”)) AND ((“primary school”) OR (“primary education”) OR (“elementary school”) OR (“elementary education”) OR (“early years”)). A total of 450 results were obtained from the databases using these search terms.

Screening

At the Screening stage of the PRISMA process, specific inclusion and exclusion criteria were applied (Table 1). Studies published prior to 2005 were not included. Additionally, studies focusing on

ITS applications in educational levels other than primary school, or in disciplines other than mathematics, were excluded. In addition, books, book chapters, conference papers, and review articles were excluded from the study as well. As a result of applying these criteria, 298 articles were eliminated. Furthermore, 14 studies with overlapping content were identified and were excluded from the study as well. Consequently, 138 articles were considered eligible for further evaluation.

Eligibility

During the eligibility stage, the titles, abstracts, methods, and results of the 138 articles were examined in detail in accordance with the predefined inclusion and exclusion criteria. Studies that were inconsistent with the scope and objectives of this research were excluded As a result of the evaluation, 114 articles were excluded from the study as they were both not in line with the aims of the study or able to meet the identified criteria. Therefore, 24 articles were chosen for analysis.

Inclusion

Titles and abstracts of all studies retrieved from the databases were screened, and duplicate or overlapping studies were removed. Subsequently, criteria such as publication year, education level, mathematics discipline, and research article status were applied to identify studies relevant to the research purpose. The full texts of the remaining studies were read and 24 articles were identified to be included in the study as a result of the evaluation.

Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria	**Exclusion Criteria**
Articles published between 2005-2025	Articles published prior to 2005
Studies addressing ITS applications at the primary school level	Studies addressing ITS applications at other education levels
Studies utilizing ITS in mathematics teaching or learning	Studies utilizing ITS in disciplines other than mathematics
Research articles	Books, book chapters, conference papers, or review articles

Results and Interpretation

In this section, the findings based on the analysis of the data obtained from 24 studies published between 2005 – 2025 are presented. The findings are discussed under the headings determined in line with the research questions.

1. **What is the distribution of the use of ITS in the literature on primary school mathematics education?**

Mathematics Domain

The reviewed studies indicate that Intelligent Tutoring Systems (ITS) used in primary school mathematics education are most frequently applied in the Numbers and Operations learning domain. The mathematics learning domains addressed in these studies are presented in Figure 2.

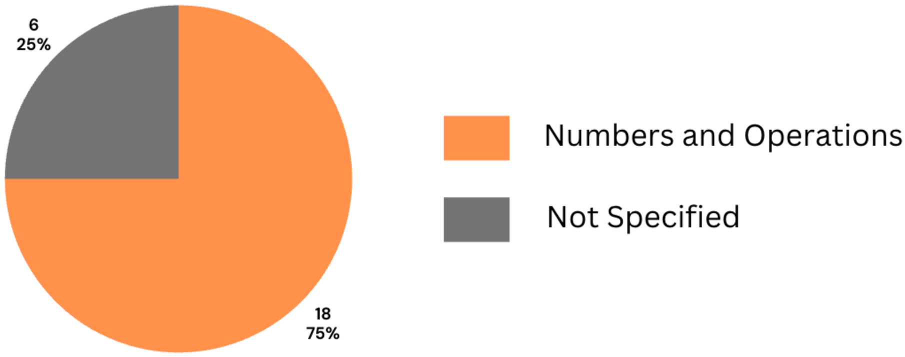

Figure 2. The distribution of the studies by mathematics domain

When Figure 2 is analysed, it can be seen that 18 studies (75%) were carried out in the Numbers and Operations learning domain (Lu et al., 2005; Sarrafzadeh et al., 2008; Pavlekoviç et al., 2010; Aguilar et al., 2011; Pareto, 2014; Rau et al., 2014; Xin et al., 2017; Bush, 2021; Chu et al., 2021; Bolsinova et al., 2022; Gocheva et al., 2022; Sperling_ et al., 2022; Knoop-van Campen et al., 2023; Levy et al., 2023; Annus and Kmet, 2024; Rodrigues et al., 2024; Sachisthal et al., 2024; Pathania et al., 2025). It was found that no mathematics domains or sub-learning domains were indicated in the 6 studies which were analysed (25%) (Chen, 2025; Joaquim et al., 2022; Moltudal et al., 2020; Karumbaiah et al., 2022; Tasdelen and Bodemer, 2025; Lin and Yang, 2021).

Some of the studies which addressed the Numbers and Operations learning domain were found to cover multiple subdomains simultaneously. Figure 3 shows the distribution of subdomains studied within the Numbers and Operations learning domain.

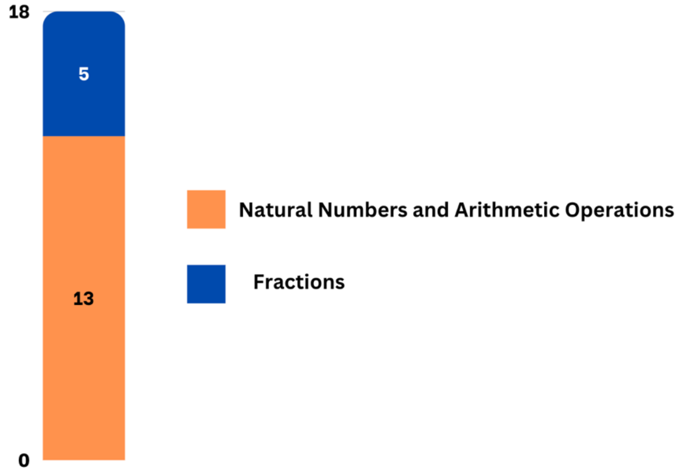

Figure 3. Subdomains studied within the Numbers and Operations learning domain

When Figure 3 is analysed, it can be seen that natural numbers and arithmetic operations with natural numbers are the most studied sub-learning domains (n=13, 72.22%) (Lu et al., 2005; Sarrafzadeh et al., 2008; Pavlekoviç et al., 2010; Aguilar et al., 2011; Pareto, 2014; Xin et al., 2017; Bolsinova et al., 2022; Gocheva et al., 2022; Sperling_ et al., 2022; Annus and Kmet, 2024; Rodrigues et al., 2024; Sachisthal et al., 2024; Pathania et al., 2025). In addition, 5 studies on the fractions sub-learning domain (27.78%) were identified (Rau et al., 2014; Bush, 2021; Chu et al., 2021; Knoop-van Campen et al., 2023; Levy et al., 2023). These findings show that ITS studies focus on a limited number of mathematics learning domains. The evaluation of the contributions of ITS on primary school mathematics education over a certain learning domain might limit the generalization of the obtained data. Therefore, there is a need for further studies on other mathematics learning domains such as geometry and quantification.

Research Method

In some of the reviewed studies, the research method was not explicitly stated (Aguilar et al., 2011; Rau et al., 2014; Bolsinova et al., 2022; Gocheva et al., 2022; Karumbaiah et al., 2022; Annus & Kmet, 2024; Sachisthal et al., 2024; Pathania et al., 2025). For these studies, the methods were inferred from the descriptions and data analyses presented in the articles. Accordingly, studies that evaluated the architecture and effectiveness of ITS developed for use in primary school mathematics education were classified as design-based research (Aguilar et al., 2011; Gocheva et al., 2022; Bolsinova et al., 2022; Annus & Kmet, 2024; Pathania et al., 2025). Studies employing correlation analyses were categorized as quantitative research (Karumbaiah et al., 2022). In addition, studies that examined both quantitative (e.g., student achievement scores, Bayesian Knowledge Tracing analyses) and qualitative (e.g., students' problem-solving processes in think-aloud sessions, observations regarding conceptual transfer) data were classified as mixed-method research (Rau et al., 2014).

One study collected qualitative statements from students. However, these statements were converted into numerical data through coding and analysed using quantitative methods (Sachisthal et al., 2024). Therefore, it was categorized as a quantitative research. In another study, although an experimental design was reported, quantitative data were collected solely to support qualitative findings, and Framework Analysis was employed during data analysis (Joaquim et al., 2022). Thus, this study was classified as a qualitative research. Figure 4 shows the distribution of research methods used in the analysed studies on the use of ITS in primary school mathematics education.

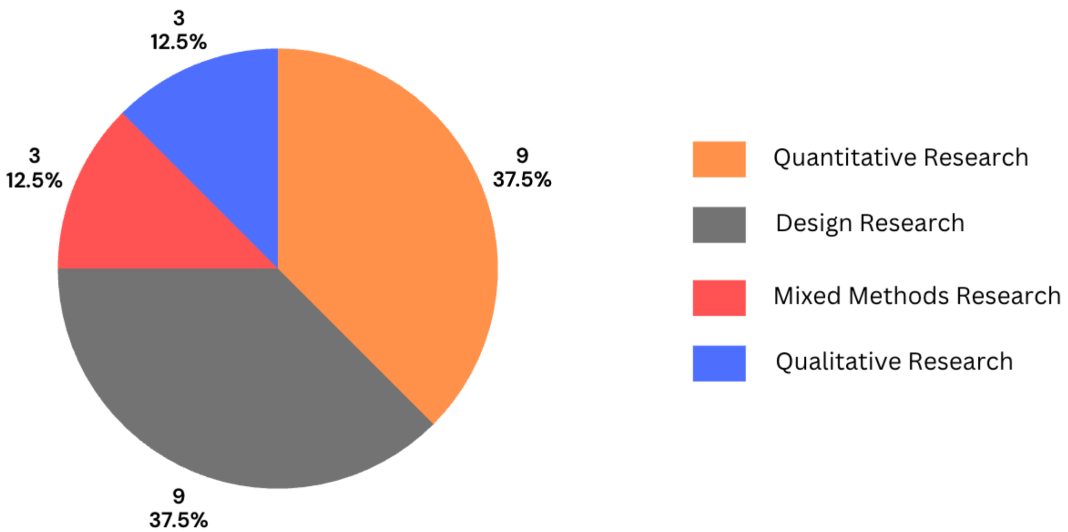

Figure 4. Distribution of research methods

When Figure 4 is analysed, it can be seen that the research methods in the studies vary. The findings show that a majority of the studies adopted the quantitative study (n=9, 37.5%) and design study approach (n=9, 37.5%). In addition, 3 of the studies made use of the mixed research design approach (12.5%) and 3 of the studies the qualitative research approach (12.5%). The dominance of quantitative and design research approaches in the studies related to the use of ITS in primary school mathematics education show that there is a strong tendency to both measure the effects of ITS on students' success and to develop the systems. However, there is a need for studies which make use of qualitative and mixed methods to be able to present the in-class interactions, pedagogical harmony and teacher and student experiences related to ITS in a more in-depth manner.

Research Results

The reviewed studies revealed that the use of ITS in primary school mathematics education made positive contributions to the learning process. A majority of the studies show that ITS increase academic achievement (n=14, %58,33) and motivation (n=7, %29,16). In addition, the studies indicate that ITS contribute to the students' problem solving skills (n=2, %8,33) and their self-sufficiency (n= 1, %4,16), develop cooperation among the students (n=2, %8,33) and increased interaction (n=1, %4,16). Furthermore, the studies indicated that the use of ITS improved collaboration among students (n=2, 8.33%) and increased interaction (n=1, 4.16%). Additionally, ITS applied in primary school mathematics education were reported to have a positive effect on knowledge retention (n=1, 4.16%). Some of the studies concluded that ITS were more effective for high-achieving students (n=2, 8.33%) and that frequency and continuity of interaction with these systems contributed positively to learning outcomes (n=2, 8.33%).

Certain studies presented noteworthy findings regarding the effects of ITS. One study reported that ITS had positive effects on all students and reduced the number of students performing below the class average (Chen, 2025). Another study emphasized that differences between school levels affected the relationship between motivation and achievement (Karumbaiah et al., 2022). Moreover, Moltudal et al. (2020) reported a decrease in motivation among students using ITS. Rau et al. (2014) highlighted that students' prior knowledge levels were a determining factor in the contribution of ITS to the learning process.

2. What opportunities and challenges have been identified in the literature regarding the use of ITS in primary school mathematics instruction?

Opportunities

Opportunities related to the use of Intelligent Tutoring Systems (ITS) in primary school mathematics instruction were classified under six themes: individualized and adaptive learning, instructional support and feedback, teacher role and workload, cognitive development, motivation, and digital literacy. The opportunities associated with the use of ITS are presented in Table 2.

Table 2. Opportunities related to the use of Intelligent Tutoring Systems

Theme	Code	f	(%)
Individualized and Adaptive Learning	Knowledge gaps	3	12.5
	Eliminating individual learning differences	16	66.66
	Providing adaptive content	3	12.5
	Manage their own learning processes	4	16.66
Instructional Support and Feedback	Enhance learning efficiency	3	12.5
	Development of students' self-regulation skills	1	4.16
Teacher Role and Workload	Reduces teachers' workload	5	20.83
	Identifying student characteristics	8	33.33
	Providing learning support	6	25
	Complementing traditional instruction	1	4.16
Cognitive Development	Conceptual understanding	6	25
	Support higher order thinking skills	2	8.33
Motivation	Increased motivation	4	16.66
Digital Literacy	Improve their digital skills	1	4.16

Table 2 shows that the opportunities primarily focus on the theme of individualized and adaptive learning. In this context, ITS contributes to addressing students' knowledge gaps (n=3, 12.5%), eliminating individual learning differences (n=16, 66.66%), providing adaptive content (n=3, 12.5%), and enabling students to manage their own learning processes (n=2, 8.33%).

Under the theme of instructional support and feedback, ITS is found to enhance learning efficiency by providing immediate feedback (n=3, 12.5%) and to support the development of students' self-regulation skills through instructional support (n=1, 4.16%). In terms of teacher role and workload, the system reduces teachers' workload (n=5, 20.83%), helps identify students' strengths and weaknesses (n=8, 33.33%), and enables timely support through feedback (n=6, 25%). Furthermore, its complementary role to traditional instruction is also identified as an opportunity (n=1, 4.16%).

Within the cognitive development theme, ITS is reported to contribute to students' conceptual understanding rather than rote memorization (n=6, 25%) and to support higher-order thinking skills (n=2, 8.33%). The motivation theme is associated with increased student motivation through making learning more enjoyable (n=4, 16.66%). Finally, in terms of digital literacy, ITS is found to help students improve their digital skills (n=1, 4.16%). The obtained data show that the use of ITS in primary school mathematics education contributes to both the learning and the teaching processes positively.

Challenges

Challenges related to the use of Intelligent Tutoring Systems (ITS) in primary school mathematics instruction were examined under six main themes: lack of social and pedagogical support, restrictive effects of the system, teacher competence, technical and design issues, student competence, and infrastructure deficiencies. These themes encompass both the practical obstacles encountered during implementation and the factors affecting the pedagogical integrity of the system. The challenges associated with the use of ITS are presented in the Table 3.

Tablo 3. Challenges related to the use of Intelligent Tutoring Systems

Theme	Code	f	(%)
Lack of Social and Pedagogical Support	Unsupervised use	1	4.16
	Lack of emotional support	1	4.16
	Limited interaction	1	4.16
	Lack of teacher support	1	4.16
	Risk of not being able to learn independently	1	4.16
Restrictive Effects of the System	Evaluating performance solely through ITS	1	4.16
	Same instructional strategy for all topics	3	12.5
Teacher Competence	Changing role of teachers	1	4.16
	Insufficient teacher preparation	5	20.83
Student Competence	Low literacy skills	2	8.33
	Negative effects of prior knowledge on learning new topics	2	8.33
	Lack of digital experience	2	8.33
	Absence of legal authorization	1	4.16
Technical and Design Issues	Effects of the system interface on achievement	1	4.16
	Mandatory system directives	3	12.5
	Programming errors	1	4.16
	Performance of the system	1	4.16
	Lack of a notes section	1	4.16
Infrastructure deficiencies	Inadequate technology and equipment	2	8.33

According to Table 3, issues such as unsupervised use (n=1), lack of emotional support (n=1; 4,16%), limited interaction (n=1, 4.16%), lack of teacher support (n=1, 4.16%), and the risk of students being unable to learn independently (n=1, 4.16%) were reported under the theme of lack of social and pedagogical support. Under the restrictive effects of the system, challenges include evaluating student performance solely through ITS (n=1, 4.16%) and the system's application of the same instructional strategy for all topics (n=3, 12.5%). Teacher competence is linked to the changing role of teachers (n=1, 4.16%) and insufficient teacher preparation (n=5, 20.83%). The student competence theme includes factors such as low literacy skills (n=2, 8.33%), negative effects of prior knowledge on learning new topics (n=2, 8.33%), lack of digital experience (n=2; 8,33%), and absence of legal authorization for data protection consent (n=1, 4.16%). Technical and design issues were reported as limitations in the system interface affecting student performance (n=1, 4.16%), the impact of mandatory system–student interaction on performance (n=3, 12.5%), miscalculations caused by programming errors (n=1, 4.16%), slowing down of the system performance in multithreading (n=1, 4.16%) and a lack of notes section for teachers (n=1, 4.16%). Infrastructure deficiencies include difficulties caused by the problems experienced due to inadequate technology and equipment (n=2, 8.33%). These findings show that the use of ITS in primary school mathematics education presents certain challenges such as social, pedagogical, teacher and student competencies and technical and infrastructure related difficulties. In this context, it can be stated that there is a need for improvement in pedagogical guidance, teacher training and technical infrastructure to be able to increase the efficiency of the system.

3. In the literature on primary school mathematics education, how have the effects of the use of ITS on students and teachers been presented?

Effects on Students

In the reviewed studies, the effects of the use of ITS in primary school mathematics education on students were grouped under two themes: positive and negative effects. The effects of the use of ITS on students are presented in the Table 4.

Table 4. Effects of ITS usage on students

Theme	Code	f	(%)
Positive Effects	Academic development	13	54.16
	Increased motivation	10	41.66
	Learning environments that consider individual differences	11	45.83
	Experiences of independent learning	5	20.83
	Collaborative learning	3	12.5
	Learning through enjoyment	3	12.5
	Learning through multiple representations	2	8.33
	Development of digital literacy skills	1	4.16
	Increasing self-sufficiency	1	4.16
Negative Effects	Decrease in motivation caused by gamification features	2	8.33
	Feeling as though they have not learned	1	4.16
	Inappropriate use of instructional support	1	4.16
	Lack of consideration for language and cultural factors in system design	1	4.16
	Low literacy skills hindering system use	1	4.16

When Table 4 is analyzed, it can be seen that academic development (n=13, 54.16%), learning environments that consider individual differences (n=11, 45.83%) and increasing motivation (n=10, 41.66%) come to the fore the most under the positive effects of the use of ITS on students theme. In addition, effects such as independent learning experience (n=5, 20.83%), collaborative learning experience (n=3, 12.5%), learning through enjoyment (n=3, 12.5%), learning though multiple representations (n=2, 8.33%), development of digital literacy skills (n=1, 4.16%) and increasing self-sufficiency (n=1, 4.16%) were underlined in the studies. Among the negative effects of the use of ITS on students in primary school mathematics education, the most notable is the decrease in motivation caused by gamification features (badges, stars) (n=2, 8.33%). Other reported negative effects include students feeling as though they have not learned (n=1; 5.5%), inappropriate use of instructional support (n=1, 4.16%), lack of consideration for language and cultural factors in system design (n=1, 4.16%), and low literacy skills hindering system use (n=1, 4.16%).

The obtained data show that ITS in primary school mathematics education have significant contributions such as increasing academic achievement and motivation and presenting individualized and adaptable learning experiences. Additionally, loss of motivation, design-learner incompatibility and usage difficulties due to low digital literacy skills reported in certain studies indicate that the effects of ITS rely on the characteristics of the learner, context of application and system design.

Effects on Teachers

The effects of Intelligent Tutoring Systems on teachers in primary school mathematics education were dealt with in various dimensions in the analysed studies. Figure 5 shows the distribution of the use of ITS in primary school mathematics education on teachers.

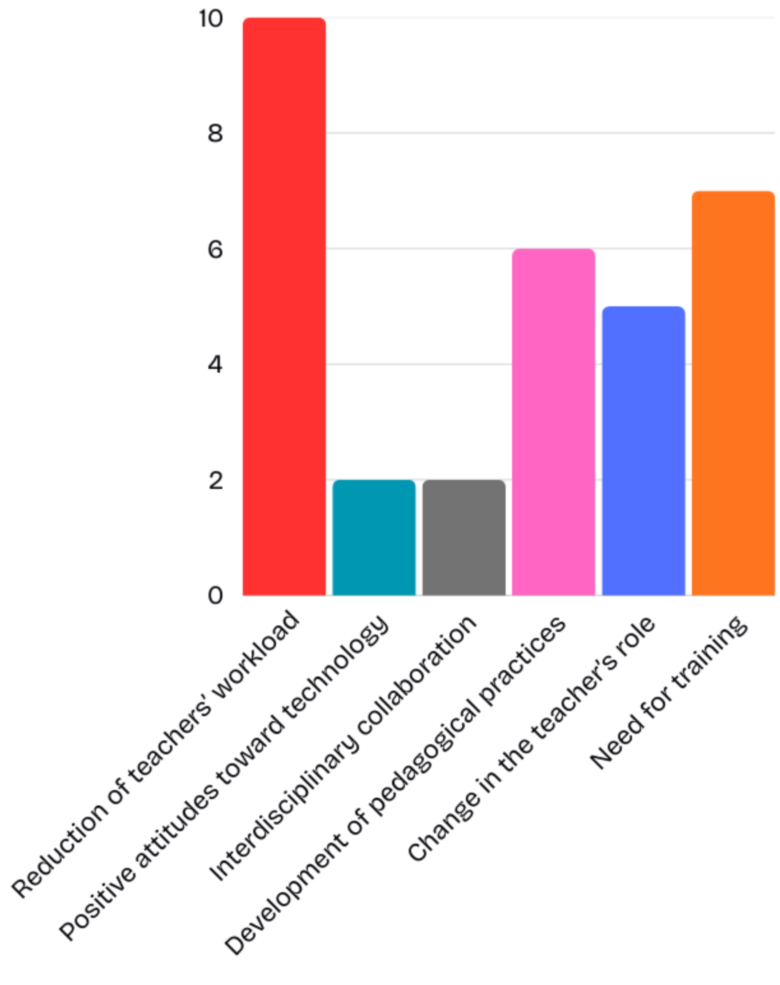

Figure 5. Effects of ITS usage on teachers

When Figure 5 is analyzed, it can be seen that the most notable effect of the system is reducing work load (n=10, 41.66%). ITS automates certain routine instructional and assessment tasks, enabling teachers to use their time more efficiently. This process also supports the development of teachers' positive attitudes toward technology (n=2, 8.33%). Additionally, the system encourages teachers to engage in interdisciplinary collaboration (n=2, 8.33%) and provides opportunities to improve their pedagogical practices (n=6, 25%). However, the use of ITS changes the teacher's role in the learning process (n=5, 20.83%) as well, shifting it toward guidance and facilitation while supporting students' independent learning. The studies emphasize that teachers need specialized training to maximize the benefits of the system (n=7, 29.16%). These findings show that ITS come to the fore as a tool which reduce teachers' workload, transform the role of teaching and support occupational development. However, it seems that the sustainability of the positive effects depends on providing quality teacher training.

Conclusion and Discussion

This study aimed to establish a framework for the use of Intelligent Tutoring Systems (ITS) in primary school mathematics education based on the existing literature and to reveal their role in the learning process. In this context, the literature review indicates that there is a limited number of studies on the use of ITS in primary school mathematics education between 2005 and 2025.

Research conducted on the use of ITS in primary school mathematics education focuses mainly on the Numbers and Operations learning domain. Accordingly, most studies on the use of ITS in mathematics education concentrate on arithmetic operations, while there are examples of applications in the subdomains of numbers and fractions as well. However, no studies were identified in the geometry, measurement, or data processing domains. This may be attributed to the fact that the subdomains of natural numbers and fractions are more suitable for ITS design (Son, 2024).

It was observed that most of the reviewed studies employed quantitative and design-based research methods, whereas qualitative approaches were scarcely represented. This indicates a gap in the literature in relation to in-depth exploration of the effects of ITS on the primary mathematics learning process and understanding the experiences of students and teachers. Han et al. (2019), in their study aiming to identify long-term trends in ITS research, also concluded that quantitative research methods were used more frequently than mixed and qualitative methods. In this respect, the findings of the present study align with the general trends in the literature.

The reviewed studies demonstrate that ITS generally makes positive contributions to the learning process in primary school mathematics education. The use of ITS has been found to significantly improve students' academic achievement, problem-solving skills, and learning motivation. Furthermore, the system supports collaboration and interaction within the learning environment and contributes to learning retention. However, some studies show that the results vary depending on individual learner characteristics and implementation conditions. It was particularly emphasized that ITS tends to be more effective for high-achieving students, and that the frequency and continuity of interaction with the system play a determining role in learning outcomes. Nevertheless, findings such as decreased motivation or the limiting effect of prior knowledge on the benefits derived from the system suggest that ITS may not be equally effective for all students (Taub & Azevedo, 2019).

The opportunities identified in the use of ITS in primary school mathematics education revolve around the theme of individualized and adaptive learning. This feature of ITS is regarded as a major advantage, as it helps to address knowledge gaps, eliminate individual learning differences, provide adaptive content, and allow students to manage their own learning processes. Indeed, many studies have discussed the role of individualization and adaptability in enhancing learning with ITS (Kim et al., 2013; Knoop-van Campen et al., 2023; Kulik & Fletcher, 2015; Mousavinasab et al., 2018; Taub & Azevedo, 2019). Therefore, it can be said that the findings of this study are consistent with the literature. Moreover, the opportunities offered by ITS in primary mathematics education are not limited to individualization and adaptability; they also include instructional support and feedback, teacher role and workload, cognitive development, motivation, and digital literacy. The results of Niño-Rojas et al.'s systematic literature review (2024) and results obtained from this study's literature review are in line with each other.

The reviewed studies also identified several challenges associated with the use of ITS in primary school mathematics education. Among these are teacher competencies, such as the changing role of teachers and insufficient preparation, and student competencies, such as low literacy skills, the negative impact of prior knowledge on learning new topics, lack of digital experience, and absence of legal authorization for data protection consent. These competencies pose challenges to the effective use of ITS in the learning process. Additionally, the restrictive effects of the system, such as a lack of social and pedagogical support, assessment of student performance solely through ITS, and the use of the same instructional strategy for all topics, as well as technical and design problems, are significant challenges in ITS implementation. Alkhatlan and Kalita (2018) noted that although ITS can standardize and implement certain aspects of human cognition and learning processes, certain limitations persist. Furthermore, infrastructural deficiencies in schools hinder both the widespread and effective use of ITS. Kulik and Fletcher (2015) also emphasized that advancements in computer hardware, software, networking, and cognitive science would influence the future structure and appearance of instructional systems.

It was determined that the use of Intelligent Tutoring Systems (ITS) in primary school mathematics education has various effects on both students and teachers. The effects on students were analysed under two main themes: positive and negative. While academic development and motivational gains were the most prominent among the positive effects, the negative effects primarily involved a decline in motivation due to gamification elements (such as badges and stars).

It was found that the most notable effect of the use of ITS for teachers was reduction of workload. This outcome supports the development of more positive attitudes toward technology among teachers. The use of ITS was reported to have a positive impact on improving teachers' pedagogical practices as well. Furthermore, it was underlined that teachers need specialized training to obtain maximum benefit from these systems. The results of this study are consistent with the commonly held view that the success of technology in mathematics education in large depends on the teacher (Drijvers, 2015).

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