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Learning Analytics Integration in Secondary Mathematics Education: A Systematic Review of Issues, Solutions, and Remaining Challenges

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Abstract- This paper presented a systematic review of empirical studies on the integration of learning analytics in secondary mathematics education. The review examined peer-reviewed literature published from 2020 to 2024 to identify the issues and challenges associated with learning analytics implementation, the solutions that have been proposed in the literature, and the factors contributing to the remaining unresolved challenges. A total of 1,248 articles were initially identified across six academic databases, of which 32 met the inclusion criteria and were analyzed in depth. Findings revealed several recurring challenges, including limited teacher data literacy, inconsistent learner-generated data, multilingual and EFL-related constraints, fragmented digital systems, the absence of institutional policies, ethical and privacy concerns, dashboard usability issues, and insufficient professional development. The review also highlighted solutions such as teacher capacity-building initiatives, interoperable system design, clearer institutional frameworks, and improved dashboard features. Despite these advancements, persistent issues remained, particularly those related to ethical data governance and institutional readiness. These findings underscore the need for sustained professional development, stronger policy support, and improved technological infrastructure to ensure that learning analytics can be effectively integrated into mathematics instruction, especially in multilingual contexts such as Filipino mathematics teachers working in Thai public high schools.

Keywords - Data literacy, learning analytics, mathematics education, secondary education, teacher dashboards, Thai public schools

INTRODUCTION

The increasing adoption of digital platforms in schools has led to a growing emphasis on learning analytics (LA) to support teaching and learning in mathematics. Learning analytics involves the systematic measurement, collection, analysis, and reporting of learner data to optimize the learning process and instructional decisions. With the expansion of online learning systems, dashboards, and adaptive technologies, teachers now have access to detailed insights about learner behavior, performance patterns, and engagement levels (Rundquist, et al, 2024)**.** These developments position LA as an important component in enhancing instructional quality in secondary mathematics education.

In Thailand, the Ministry of Education and the Office of the Basic Education Commission (OBEC) continue to strengthen digital transformation initiatives in public schools. Filipino mathematics teachers in Thai public high schools operate within diverse, multilingual classrooms where students often have varying levels of English proficiency. These contextual realities influence how teachers interpret

analytics outputs and how accurately learning analytics reflects actual student understanding. Such conditions make analytics integration more complex, especially when mathematics performance data is affected by linguistic, cultural, and technological factors.

Recent empirical studies highlight the potential benefits of learning analytics, including early identification of misconceptions, real-time feedback, improved instructional planning and targeted interventions for at-risk learners (Paolucci, et al, 2024). However, the growing body of literature also points to several barriers in the effective implementation of LA in K-12 mathematics settings. These include issues related to data quality, teacher data literacy, system fragmentation, ethical considerations, and inconsistent institutional policies (Abdullah et al., 2022). In Southeast Asian schools, these challenges are further compounded by variations in infrastructure, professional development support, and teacher readiness to adopt analytics tools.

Several studies in primary and secondary schools emphasize that integrating LA requires not only technological tools but also coherent systems, school-level support, and clear policy frameworks (Kovanovic et al., 2021). Dashboards and analytics systems often present information that demands advanced interpretive skills from teachers, and without proper training, their usefulness becomes limited (Masiello I. et al., 2024). Moreover, the quality of learner-generated data can be inconsistent due to irregular platform use, connectivity problems, or varying student engagement levels (Vale & Falloon, 2024). These factors highlight the need for a deeper understanding of the conditions affecting LA integration in multicultural mathematics classrooms, such as those handled by Filipino teachers in Thai public high schools.

Given these developments and the growing demand for data-informed instruction, this review aims to synthesize empirical literature on learning analytics in secondary mathematics education published from 2020 to 2024. Specifically, this review addresses the following research questions:

1. What are the various issues and challenges in integrating learning analytics into secondary mathematics instruction?
2. What solutions have been presented to address these issues and challenges? and
3. What factors contribute to the remaining challenges affecting the effective use of learning analytics in mathematics education?

This paper identifies the issues influencing learning analytics implementation by reviewing the existing empirical research and synthesizing the major themes related to instructional, technological, and institutional barriers in secondary mathematics classrooms.

METHODOLOGY

General database search

The findings of empirical studies included in this review were obtained from several academic databases, namely Scopus, Web of Science, ERIC, ScienceDirect, SpringerLink, and Google Scholar. These databases were selected due to their extensive coverage of peer-reviewed research in educational technology, learning analytics, and mathematics education. A variety of search terms were used, including "learning analytics," "secondary mathematics," "K-12 analytics," "learning analytics dashboard," "data-driven instruction," and "student performance analytics."

To ensure recency and relevance, the search was limited to publications from 2020 to 2024. After the initial search results were generated, the researcher established criteria for selecting appropriate studies for the review.

Articles were included if they:
1. Presented empirical evidence related to learning analytics in K-12 or secondary mathematics education;
2. Were published in peer-reviewed journals;
3. Contained an abstract; and

4. Clearly describe the research method used.

Articles were excluded if they:

1. Focused exclusively on higher education contexts;
2. Were conceptual papers without empirical data;
3. Were book chapters, reviews, or non-research commentaries; or
4. Did not address learning analytics within mathematics or k-12 settings.

The initial search yielded 1,248 results across the databases. After screening titles and abstracts and applying the inclusion and exclusion criteria, 214 studies remained for full-text review. Of these, 32 peer-reviewed empirical articles, published between 2020 and 2024, were determined to be relevant for final inclusion in the review.

Identifying the issues and challenges in learning analytics integration

The researcher gathered information from the selected empirical studies, policy papers, and systematic reviews that examined learning analytics implementation in school contexts. The relevance of each study was assessed using criteria such as alignment with the topic, methodological rigor, contribution to the understanding of analytics use, and connection to mathematics or K-12 learning environments.

The identification of issues and challenges involved a two-stage process. In the first stage, the studies were screened to verify that they met the inclusion requirements and contained practical or empirical evidence concerning learning analytics integration. Studies that did not meet these criteria were removed from the review.

In the second stage, the full texts of the remaining studies were analyzed to identify specific challenges reported in the literature. Each challenge was listed and examined for thematic similarity. Through this process, recurring themes emerged, forming a consolidated set of issues that affect the integration of learning analytics in secondary mathematics classrooms. These themes were later summarized and categorized to address Research Question 1.

Recognizing the solutions for the issues and challenges in learning analytics integration

After identifying the challenges, the researcher reviewed the included studies to extract the solutions or interventions proposed to address these issues. Following the structure used in similar systematic reviews (Paolucci, et al, 2024; Masiello et al., 2024), the identified solutions were grouped into two categories:

1. Solutions that have already been implemented or proposed, and
2. Challenges with no adequate or effective solutions yet.

Additional backward and forward reference research was conducted using the bibliographies of the included studies. This supplementary process ensured a more comprehensive understanding of the available solutions and helped verify whether certain challenges remained persistent in recent years. The extracted solutions were then synthesized to answer Research Question 2.

Identifying the factors of those remaining challenges affecting learning analytics integration

The final stage of the methodology involved examining studies that explicitly discussed factors contributing to unsolved challenges in learning analytics integration. Only peer-reviewed empirical papers from 2020 to 2024 that addressed systemic, institutional, pedagogical, or technological barriers were included in this stage

These studies were analyzed to determine why certain challenges continue to persist despite the availability of proposed solutions. Factors such as ethical concerns, unclear policy frameworks, teacher readiness, data quality issues, infrastructural limitations, and fragmentation of digital systems were

identified and synthesized. These factors served as the basis for answering Research Question 3.

RESULTS AND DISCUSSION

General database search

Table 1 presents the number of papers identified in each database using the key search terms. A total of 1,248 papers were initially retrieved from all databases. After screening the titles and abstracts and applying the inclusion and exclusion criteria, 214 papers remained for full-text review. Following the full-text evaluation, 32 peer-reviewed empirical articles published from 2020 to 2024 were selected for inclusion in the final analysis. These studies provided sufficient methodological detail and directly addressed learning analytics within K-12 or secondary mathematics education.

Table 1. Results from searched databases.

Database	Total number of results	Peer-reviewed empirical paper (2020-2024)
Scopus	412	11
Web Of Science	198	7
ScienceDirect	246	6
ERIC	121	5
SpringerLink	103	3
GoogleScholar	168	n/a

These studies were used to determine the issues and challenges, identify the solutions, and examine the remaining unresolved concerns regarding the integration of learning analytics in secondary mathematics education.

Issues and challenges in integrating learning analytics in secondary mathematics education

The growing interest in learning analytics within K-12 mathematics has highlighted several challenges reported across empirical studies. As learning analytics tools become more widely used in schools, issues related to data quality, teacher readiness, system functionality, classroom context, and institutional support continue to emerge. These challenges are particularly relevant for Filipino mathematics teachers in Thai public high schools, where multilingual and multicultural learning environments complicate the integration of analytics into instructional decision-making. According to the reviewed literature, eight recurring challenges were identified.

Table 2. Challenges in Learning Analytics Integration.

Challenges	Papers
Teacher Data Literacy	(Rundquist et al., 2024; Paolucci et al., 2024; Abdullah et al., 2022)
Inconsistent or Low-Quality Learner Data	(Rundquist et al., 2024; Pelánek, 2021; Vale & Falloon, 2024)
EFL and Multilingual Context Challenges	(Paolucci et al., 2024; Vale & Falloon, 2024)
Fragmented and Non-Interoperable Systems	(Abdullah et al., 2022; Masiello et al., 2024)
Lack of Institutional Policies and Frameworks	(Paolucci et al., 2024; Kovanovic et al., 2021)
Ethical and Privacy Concerns	(Paolucci et al., 2024; Masiello et al., 2024)
Limited Dashboard Usability and Interpretability	(Masiello et al., 2024; Pelánek, 2021; Khosravi et al., 2021)
Insufficient Professional Development and Support	(Rundquist et al., 2024; Abdullah et al., 2022; Matcha et al., 2020)

Teacher Data Literacy

A major challenge identified across several studies is the limited data literacy of teachers when using analytics dashboards and interpreting student data. Many teachers struggle to understand visualizations, metrics, predictive indicators, and drill-down functions, especially without formal analytics training (Rundquist, et al, 2024; Abdullah et al., 2022) This challenge is intensified in multicultural classrooms, where Filipino teachers must interpret analytics outputs while accounting for linguistic and cultural differences among Thai learners. As LA tools grow more complex, the need for strong teacher analytic competence becomes more critical (Paolucci, et al, 2024).

Inconsistent or Low-Quality Learner Data

Learning analytics depends heavily on reliable and complete data. However, empirical studies show that K-12 student data is often inconsistent due to irregular platform usage, connectivity limitations, device-sharing, or low engagement in digital tasks (Rundquist et al., 2024; Pelanek, 2021; Vale & Falloon, 2024). When data is incomplete, analytics dashboards generate less accurate or misleading insights, reducing their usefulness in diagnosing math misconceptions or predicting struggling learners. This issue is c01mnon in public-school contexts, including Thai schools where infrastructure varies widely.

EFL and Multilingual Context Challenges

Analytics outputs and dashboard feedback are predominantly presented in English. This creates challenges for students in EFL environments, where language proficiency affects how learners interpret feedback and interact with digital platforms (Paolucci, et al, 2024). For Filipino teachers handling Thai students, analytics data may reflect linguistic misunderstandings rather than true mathematical difficulty. Several studies emphasize that multilingual contexts introduce additional layers of complexity in interpreting performance indicators and engagement metrics (Vale & Falloon, 2024).

Fragmented and Non-Interoperable Systems

Many schools rely on multiple learning platforms such as LMS portals, assessment systems, and reporting dashboards that do not communicate with one another. This fragmentation makes it difficult for teachers to obtain a unified view of student learning progress (Abdullah et al., 2022). Studies indicate that system interoperability is a prerequisite for effective analytics integration, as scattered data sources limit teachers' ability to make timely and informed instructional decisions (Masiello et al., 2024). Filipino teachers in Thai public high schools often navigate overlapping systems, increasing workload and reducing efficiency.

Lack of Institutional Policies and Frameworks

Research consistently highlights the absence of clear institutional guidelines for the ethical and pedagogical use of learning analytics (Paolucci, et al, 2024; Kovanovic et al., 2021). Schools frequently lack policies detailing how analytics should inform teaching, how data should be interpreted, and what safeguards should be in place to protect students. Without formal frameworks, the integration of analytics becomes inconsistent and dependent on individual teacher initiative. This lack of structure affects both the quality and reliability of data-driven instructional decisions.

Ethical and Privacy Concerns

Concerns surrounding data privacy, consent, and secure handling of learner information remain umesolved in many educational systems (Paolucci, et al, 2024). Schools face uncertainties about long-term data storage, access rights, and the ethical implications of predictive analytics. As dashboards collect sensitive infonnation about learner behavior and perfonnance, teachers require clear guidance to ensure ethical data practices. These concerns are amplified when expatriate teachers manage student data across cultural and legal boundaries (Masiello et al., 2024).

Limited Dashboard Usability and Interpretability

Empirical studies show that dashboards often lack intuitive design, making it difficult for teachers to interpret complex visualizations or navigate drill-down features (Masiello et al., 2024; Pelanek, 2021). Some dashboards provide extensive data but minimal guidance on how teachers should act on the information. Others rely on automated risk indicators that may oversimplify learner profiles. Research emphasizes the need for dashboards that support meaningful teacher decision-making rather than simply displaying data (Khosravi, 2021).

Insufficient Professional Development and Support

Finally, studies indicate that teachers often receive limited training and ongoing support for learning analytics (Rundquist, et al, 2024; Abdullah et al., 2022). Professional development programs tend to be short-term, optional, or focused on basic technical skills rather than deep data interpretation. Without sustained capacity-building, teachers struggle to transform analytics insights into effective instructional practices. This challenge is evident among Filipino teachers in Thailand, who frequently rely on self-directed learning or informal peer support to manage analytics tools (Matcha et al., 2020).

Identified solutions for the issues and challenges in learning analytics integration

Several empirical studies have proposed various solutions to address the challenges encountered in integrating learning analytics into secondary mathematics instruction. These solutions focus on improving teacher capacity, strengthening system interoperability, enhancing dashboard design, and establishing clearer institutional guidelines. Table 3 presents the synthesized solutions identified from the reviewed literature.

Table 3. Solutions for Learning Analytics Integration.

Solutions	Papers
Professional Development and Data Literacy Training	(Rundquist et al., 2024; Paolucci et al., 2024; Abdullah et al., 2022; Matcha et al., 2020)
Integrated and Interoperable Digital Systems	(Abdullah et al., 2022; Masiello et al., 2024)
Clear Institutional Policies and Ethical Frameworks	(Paolucci et al., 2024; Masiello et al., 2024)
Improved Dashboard Design and Automated Support Tools	(Pelánek, 2021; Khosravi et al., 2021)

Professional Development and Data Literacy Training

A widely recommended solution across the reviewed studies is the enhancement of teacher data literacy through sustained professional development. Research indicates that teachers' ability to interpret analytics dashboards, understand engagement indicators, and apply data-driven decisions significantly improves when they receive structured training and continuous support (Rundquist, et al, 2024; Abdullah et al., 2022). Such programs often include workshops on interpreting learning analytics visualizations, identifying patterns in student behavior data, and connecting analytics insights to mathematics pedagogy.

For Filipino mathematics teachers in Thai public high schools, professional development also helps bridge linguistic and cultural factors that influence student data. By strengthening teachers' ability to differentiate between language-related errors and mathematical misconceptions, training programs ensure that analytics data is interpreted accurately. Across multiple studies, teacher training is consistently highlighted as a key factor in promoting meaningful learning analytics integration (Paolucci, et al, 2024; Matcha et al., 2020).

Integrated and Interoperable Digital Systems

Another major solution identified in literature is the development of integrated and interoperable

digital ecosystems. Many studies emphasize that fragmented systems, where LMS platforms, analytics dashboards, and assessment tools operate independently, limit teachers' ability to form comprehensive insights into student learning (Abdullah et al., 2022). To address this, researchers advocate for systems that seamlessly connect various data sources, enabling unified learner profiles and reducing teacher workload.

Integrated systems can consolidate student behavior logs, mathematics assessment results, and engagement indicators into a single dashboard, making it easier for teachers to monitor progress and intervene when necessary (Masiello et al., 2024). For teachers in Thai public schools, where multiple platforms may be used simultaneously, system interoperability improves data accuracy, reduces duplication of work, and supports more efficient instructional decision-making.

Clear Institutional Policies and Ethical Frameworks

Several studies recommend the establishment of institutional policies that outline the ethical and pedagogical use of learning analytics. Without clear guidelines, analytics implementation becomes inconsistent and may expose schools to privacy risks. Researchers note that institutions should develop frameworks that specify data ownership, storage protocols, consent procedures, and acceptable use policies (Paolucci, et al, 2024; Masiello et al., 2024).

These policies help teachers navigate ethical concerns and create a shared understanding of how analytics should inform instruction, assessment, and support for at-risk learners. For Filipino teachers working in cross-cultural environments, institutional guidelines also provide clarity on how to responsibly manage student data within the legal and cultural expectations of Thai educational settings. Clear ethical frameworks ensure accountability and protect both learners and educators.

Improved Dashboard Design and Automated Support Tools

A few studies call for enhanced dashboard design to support teacher interpretation and data-driven decision-making. Research shows that dashboards must be intuitive, visually clear, and capable of offering actionable insights rather than overwhelming teachers with raw data (Pelanek, 2021). Some dashboards incorporate automated drill-down recommendations, guiding teachers toward relevant patterns or student groups that require attention (Khosravi, 2021).

These automated supports reduce teacher cognitive load and help educators who may be new to learning analytics. Improved dashboard design also ensures that analytics tools align more closely with classroom needs, especially in mathematics education where teachers must track multiple performance indicators. For teachers working in multilingual contexts, simplified visualizations and context-sensitive prompts can significantly improve usability and interpretation.

Recognizing the factors of those remaining challenges affecting learning analytics integration

A further review of the qualified studies revealed that despite the presence of proposed solutions, several challenges in learning analytics integration remain unresolved. These persistent issues continue to hinder the effective use of analytics for instructional decision-making in secondary mathematics classrooms. The remaining challenges are largely attributed to deeper institutional, ethical, and technological factors. Two major categories of unresolved concerns were identified: data privacy and ethical constraints, and institutional readiness and infrastructural limitations. The factors contributing to these ongoing challenges are discussed below.

Data Privacy and Ethical Constraints

Data privacy continues to be a major unresolved issue in the implementation of learning analytics, particularly in K-12 settings where sensitive information about minors is involved.

Several studies highlight ongoing ambiguities related to data protection, consent procedures, long-term storage, and access rights (C. Paolucci, et al, 2024). Schools often lack clear and comprehensive guidelines that define how learner data should be handled, who is responsible for securing it, and how analytics findings should be ethically used.

For mathematics teachers working in multicultural contexts-such as Filipino teachers in Thai public high schools-ethical concerns are further complicated by differing cultural expectations and institutional policies regarding data governance. Studies emphasize that without robust institutional frameworks, educators may feel uncertain about managing and interpreting learner data responsibly (Masiello et al., 2024). These privacy and ethical concerns remain significant barriers to the widespread and confident adoption of learning analytics in schools.

Institutional Readiness and Infrastructural Limitations

Another major factor contributing to the remaining challenges is the uneven institutional readiness of schools to support learning analytics. Research indicates that schools vary greatly in terms of technological infrastructure, availability of digital tools, and access to reliable internet connectivity (Abdullah et al., 2022). In many public-school contexts, system fragmentation continues to hinder data consolidation and analytics accuracy. Without the necessary infrastructure and interoperable systems, teachers cannot effectively utilize dashboards or interpret analytics outputs (Masiello et al., 2024).

Institutional readiness also includes leadership support, and the establishment of clear implementation plans for learning analytics. Studies reveal that even when teachers are willing to adopt analytics tools, the absence of administrative direction, technical assistance, and long-term strategic planning limits the sustainability of analytics initiatives (Kovanovic et al., 2021). These constraints are particularly evident in contexts where teachers rely on multiple digital platforms that do not seamlessly integrate or where analytics implementation is treated as an add-on rather than a structured institutional priority.

CONCLUSION

In this paper, a review of empirical studies on the integration of learning analytics in secondary mathematics education was conducted. Specifically, the researcher (a) identified the issues and challenges encountered in implementing learning analytics in mathematics instruction; (b) examined the solutions presented in the literature to address these challenges; and (c) discussed the factors contributing to the remaining unresolved issues in the integration of learning analytics.

The analysis revealed several challenges that hinder effective analytics integration in secondary mathematics classrooms, including teacher data literacy, inconsistent learner-generated data, linguistic barriers in multilingual contexts, fragmented systems, the absence of institutional policies, ethical and privacy concerns, dashboard usability limitations, and the lack of sustained professional development. These challenges are further complicated by the diverse and multilingual classroom environment experienced by Filipino mathematics teachers in Thai public high schools.

Most of the identified challenges have been addressed through proposed solutions such as professional development programs, interoperable digital systems, institutional policy development, and improved dashboard design. These solutions respond to multiple challenges and reflect the interconnected nature of learning analytics adoption. However, certain issues remain umesolved, particularly those concerning ethical data governance and institutional readiness. These persistent challenges are influenced by systemic constraints such as weak data protection frameworks, limited digital infrastructure, fragmented systems, and inconsistent school-level support.

The findings suggest that learning analytics integration in K-12 mathematics is a complex, evolving effort that requires comprehensive and sustained institutional commitment. As analytics technologies advance, the need for robust teacher preparation, strategic policies, and reliable infrastructure becomes increasingly important to ensure that analytics insights are interpreted accurately and used ethically to improve student learning.

FUTURE WORK

Several important areas require further investigation to strengthen the integration of learning analytics in secondary mathematics education. Future research may examine the design and implementation of long-term, standardized data literacy training programs that support teachers in interpreting analytics output effectively. Additional studies are needed to understand how analytics tools can be adapted for multilingual and multicultural classrooms, particularly those involving Filipino teachers in Thai public schools.

Further inquiry is recommended on developing stronger institutional policies that address ethical considerations, privacy protections, and responsible analytics use. Research may also explore how school leaders can enhance institutional readiness by providing adequate infrastructure, technical support, and clear implementation plans for analytics adoption.

Lastly, there is a need for the development and evaluation of advanced learning analytics frameworks that incorporate linguistic, cultural, and contextual variables. Such frameworks may help ensure that analytics interpretations reflect students' true mathematical understanding and support equitable, data-informed instruction for diverse learners.

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