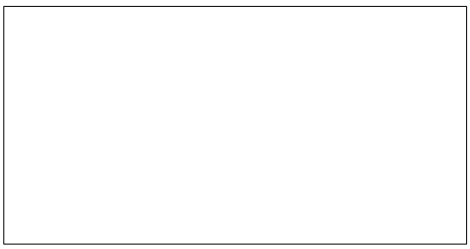

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A systematic literature review on software applications used to support curriculum development and delivery in primary and secondary education

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ABSTRACT

The evolution of educational software applications has revolutionised teaching and learning methodologies in primary and secondary education over the past decade. This paper conducts a review of primary studies based on $N = 21$ papers published between 2013 and 2023, focusing on the diverse landscape of software applications designed for student learning, curriculum development, delivery, and assessment. Findings from this study showcases a range of software solutions ranging from assessment tools to tutoring applications. Distinctive features supporting various aspects of teaching and learning, including lesson planning, delivery, management, assessment, and self-directed learning, were also identified. Regarding the features of software solutions used in primary and secondary schools, some differences were identified in terms of complexity, interactivity, assessment methodologies, and the collaborative functionalities of these tools. While highlighting the potential benefits, findings from this study also showed that challenges such as deployment costs, user self-efficacy, and technology anxiety are influential factors affecting the adoption of these technologies in primary and secondary educational settings. The evidence presented in this study serves as a resource for educational leaders and practitioners, facilitating a deeper understanding of available educational tools and essential considerations in the design and adoption of future tools.

1. Introduction

Educational software applications have facilitated the development of new approaches to teaching and learning (Bova et al., 2015). These programs are specifically designed to perform tasks that facilitate teaching and learning processes. Educational software applications include learning management systems, assessment tools, tutoring systems, content creation platforms, recommendation engines, simulation programs, and gamification tools. The significance of educational software applications rests in their ability to transform traditional teaching methods into more efficient, engaging, and personalised learning experiences. According to Haleem et al. (2022), conventional teaching and evaluation standards have shown various limitations such as slower evaluations and weaker engagement as opposed to digital learning environments that have shown efficiency in filling this void. A study conducted Lima et al. (2017) shows that teachers and students now express higher interests in acquiring more knowledge, owing to the development of more personalised and robust techniques in educational applications. Modern teaching and learning are a representative of efficient methodologies adopted through the use of educational software applications (Bova et al., 2015). A study conducted by Zakaria et al. (2017) suggests that integrating activities that support collaboration among students is an important feature to integrate into state-of-the-art educational software applications. These applications will incorporate cutting-edge features like artificial intelligence, machine learning, and advanced analytics, which enable more personalised and efficient educational experiences. Various attempts have been made to introduce software applications that are aimed at performing specific tasks in primary and secondary education ranging from lesson planning to evaluating student performance. For instance, an AI based E-learning system is presented by Khanal et al. (2020), which facilitates learning in secondary schools. Ngadiman et al. (2021) presented an intelligent virtual educational platform that aims to improve the efficiency of teaching primary school students in developing countries by inferring new activities that students find more engaging using data generated by students. Also, the design, development and trial of a classroom evaluation system that supports K-12 formative assessment is also presented by Campoverde-Molina et al. (2021).

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The rapid advancement of technology and its integration into education necessitates an updated understanding of current tools, practices and their effectiveness. Also, identifying trends and gaps in the literature can inform educators, policymakers, and developers about successful strategies and areas needing improvement. Finally, synthesising recent research provides a comprehensive overview that can guide future innovations and implementation efforts, ensuring that educational tools are both effective and relevant in modern classrooms. Therefore, this systematic literature review (SLR) aims to identify primary studies over the last decade (2013 to 2023) on educational software applications used for student learning, curriculum development, delivery and assessment in primary and secondary education.

The remainder of this paper is organised as follows: Section 2 provides a review of related research efforts. Section 3 provides details of the methodology adopted in this systematic literature review, highlighting the research questions, relevant criteria for selecting primary studies and the approach for assessing the quality of papers. The results and discussion is presented in Section 4, and Section 5 concludes the paper.

2. Related work

The educational field has seen a surge in the use of advanced technologies to support teaching and learning activities. This interest has led to numerous efforts by the scientific community to develop new use cases and summarise the state of educational software applications over the last decade. The following subsections highlight some SLRs into various aspects of systems and applications used in educational settings.

2.1. Software quality in educational applications

A study was conducted by Ngadiman et al. (2021) on software quality in educational applications. The study focused on two characteristics of quality, such as effectiveness and satisfaction, and three usability sub-characteristics such as user interface aesthetic, learnability, and appropriateness recognisability that are useful for evaluating the quality of such educational applications. The results provide an insight on important considerations, specifically in developing educational applications.

2.2. Software architecture of educational websites

Campoverde-Molina et al., (2021) conducted a SLR on the software architecture of educational websites. The study search yielded 23 primary studies showcasing methodologies, technological components and empirical results on different software architectures used in educational websites. Findings from this study showed that educational websites are largely developed based on a "layered architecture", where related functionalities are grouped in different vertical layers to accommodate different client types or devices and support the implementation of complex business rules. The study also showed that the "model-driven engineering" methodology for software development is a widely used approach in the development of educational websites.

2.3. Mobile learning in primary and secondary education

Crompton et al. (2017) conducted a systematic literature review on mobile learning in PK-12 education. This study synthesised findings from research published between 2010 and 2015, focusing on how mobile devices such as tablets and smartphones are used in classrooms. The review found that mobile learning applications can significantly improve access to educational resources and facilitate personalised learning experiences. However, challenges such as device management, digital equity, and the need for teacher training were identified as barriers to widespread adoption. Findings from our study also reveals the need for adequate teacher training to fully utilise the functionalities of educational tools, to curb the issue of technology anxiety and low self-efficacy among users of these tools (Abdullah et al., 2016; Zheng & Li, 2020).

2.4. Virtual reality in K-12 and higher education

Merchant et al. (2014) reviewed the use of virtual reality (VR) K-12 and higher education. The review examines how VR applications can enhance learning experiences by providing immersive environments that simulate real-world scenarios. The findings indicate that VR and game-based technologies are effective in improving understanding and motivation, particularly in subjects like science. However, high costs and the need for technical support were identified as existing challenges, which aligns with a recent study conducted by Bower et al. (2020), identified in our findings.

2.5. Personalisation and adaptation in educational systems

According to recent studies, some important features of new educational systems consider the different characteristics in learners such as competency levels, learning styles and learning activities to generate contents that suit the preference and interests of learners. For instance, study conducted by Ashraf et al. (2021) was directed towards course recommender systems to filter irrelevant learning resources and provide more personalised content for learners. The authors conducted a comprehensive review and presented a summary of parameters and techniques used by educational recommender systems. In addition, their study defined a taxonomy of factors that should be considered in the process of recommending courses. Similarly, a review was also conducted by Salazar et al. (2021) on affective recommender systems, which are theoretically based on the assumption that emotions affect decision making. In the study, pioneer authors and research trends on different recommender systems were identified, and various techniques used in affectivity analysis and modelling emotions were also summarised. The authors also suggested the need for analysing the impact of changes in student emotions over time in their use of recommendation systems for educational purposes, to inform pedagogical strategies, learning styles and types of content to be used in subsequent lessons.

As new technological solutions have enabled the development of more sophisticated educational applications that generate personalised content using various resources, it has become necessary to identify technological solutions that aim to improve specific aspects of teaching and learning in different levels of education. As far as the authors are aware, there are no broad scope of secondary studies that consolidate research investigations that addresses the distinctions between features of educational applications and frameworks used within the different levels of education.

This review aims to contribute to knowledge in this field of research by conducting detailed investigations to provide more insights into the types of software applications and frameworks used in supporting curriculum development and delivery with a focus on primary and secondary education.

3. Methodology

A systematic literature review (SLR) methodology is adopted in this study to gather evidence from primary research efforts investigating software applications and frameworks used in primary and secondary education. According to Kitchenham and Charters (2007), this method promotes impartiality and enables the reproducibility of the review to corroborate evidence from current research. Therefore, the development of a review protocol is integral to guide the process of selecting primary studies and extracting relevant data for analyses.

Various guidelines for conducting SLRs have been described in literature to gather evidence from different domains such as social science and medicine (Petticrew & Roberts, 2008; Khan, et al., 2003). In

the area of informatics and software engineering, the guidelines presented by Kitchenham and Charters (2007) have been reported as the most popular adaptation (Da Silva et al., 2023). In light of this, the guidelines presented by Kitchenham and Charters (2007) were employed in our SLR. In these guidelines, three main phases are involved in a review, which are; planning, conducting and reporting the review. By adapting these orientations, we structured the SLR into three stages with seven steps distributed across each phase as seen in Fig. 1.

3.1. Planning the review

In the first phase (planning the review), we identified the need for conducting a SLR to investigate current software applications and systems used in primary and secondary education. In step one, we carried out a search for secondary studies on the intended breadth of this study. From the results, it was evident that there have been no prior efforts that fall within our review scope. In step two, the review protocol was developed, outlining the processes involved in the SLR. The protocol was revised and clarified through series of discussions between authors until a colclusion was reached, leading to agreement on the research questions, the search process and the selection/extraction of data from primary studies.

3.1.1. Research questions

The development of research questions helped in defining questions that this study aims to investigate in an attempt to identify and synthesise available information on the types, components and relevant considerations on software applications used in primary and secondary education. After discussions with the research team, the questions to be addressed in this study are presented in Table 1.

3.1.2. Sources of primary studies

In order to explore a wide range of publications that are relevant to this study, a combination of five popular repositories that are relevant to computer science and education were used during the initial search for primary studies. These repositories included IEEE Xplore, ACM, ScienceDirect, Web of Science, Education Resource Information Centre (ERIC).

3.1.3. Defining the search strings

During the search process, we stated specific keywords that were

Table 1
Research questions for SLR.

SN	Research questions	Rationale
RQ1	What software applications and frameworks used in primary and secondary education are discussed in literature?	Software applications and frameworks used in primary and secondary education are designed to aid in key aspects of teaching the curriculum, enhancing numeracy and literacy of students and monitoring their progress through assessments. This question aims to identify the types of educational software applications and frameworks discussed in literature that aids curriculum development and delivery.
RQ2	What are the features and components of software applications and frameworks used in primary and secondary education?	As new technologies are used in educational settings to support different aspects of teaching and learning, this question aims to identify key features and components of educational software applications that are relevant to primary and secondary education.
RQ3	What are the differences between the features of applications and frameworks used in primary and secondary education?	Teachers in primary education tend to approach new strategies with higher flexibility as opposed to teachers in secondary schools who predominantly follow a structured approach to curriculum delivery. This question aims to identify some key differences in the features of software applications and frameworks used in primary and secondary schools.
RQ4	What limitations in the adoption of existing educational software solutions are discussed in literature?	This question aims to identify possible factors that hinder the adoption of new educational software applications and frameworks.
RQ5	What are the measurable impacts of existing educational software applications on teaching and learning in primary and secondary education?	This question aims to identify some evidence-based research that discusses the impact of educational applications on curriculum development and delivery.

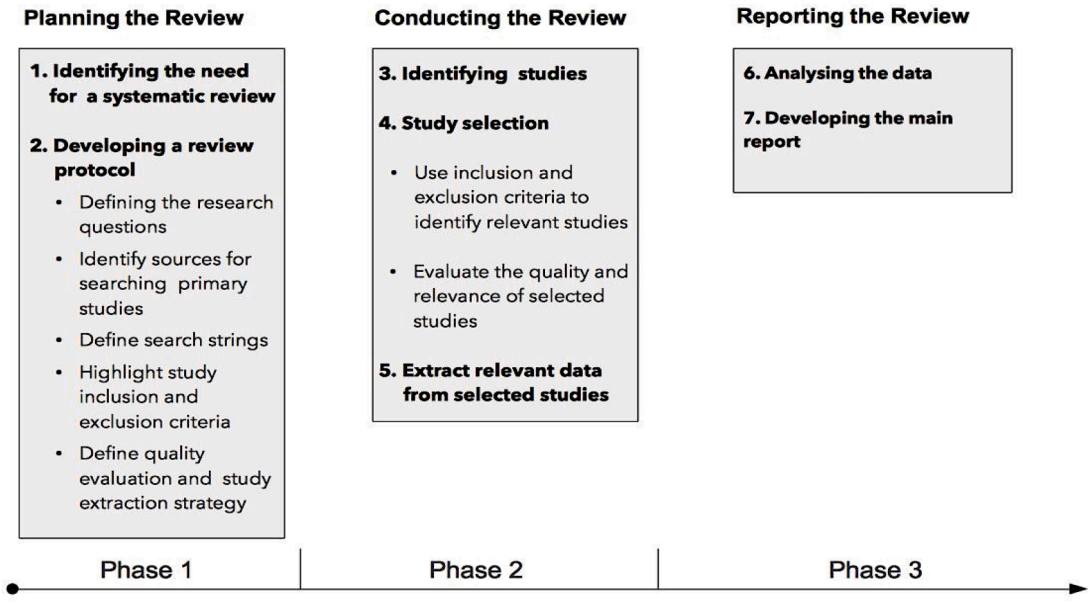

Fig. 1. SLR phases and tasks.

Table 2
Search strings and repositories used in the SLR.

Context	Strings
Education	Primary OR secondary OR education OR educational OR school OR classroom OR curriculum OR K-12 OR "state sector" (Title)
Context	teach*OR lesson OR learn* OR assess* OR feedback OR exam* OR resource OR "adaptive learning" OR "self-regulated learning" (All Fields)
Software	AI OR "artificial intelligence" OR Software OR application OR "software application" OR system OR tool OR product OR web OR "web site" OR website OR development OR content OR project (Title)

required as output in the paper titles and keywords that may appear within the body of each paper (see Table 2). For instance, using the advance search feature in each repository, we specified keywords such as Primary OR secondary (Title) AND AI OR "artificial intelligence", forcing the search engine to return papers with the specified keywords in their titles. Some additional keywords such as teach*OR lesson (All Fields) AND development OR content (All Fields) were also included in the search keywords to identify papers with the relevant titles that contain these keywords within the body of the papers.

3.1.4. Study inclusion and exclusion criteria

After obtaining results from the initial search for primary studies, the selection of papers began by applying a set of inclusion and exclusion criteria. This process essentially identified primary studies that are potentially appropriate for the scope of the SLR. Since our focus is to identify current frameworks and trends in the use of educational software applications in primary and secondary schools, we considered studies published over a 10-year period (2013 to 2023) due to various reasons. Firstly, this period marks significant technological advancements and increased integration of digital tools in education, providing a rich context for examining the evolution and impact of educational software applications. Additionally, selecting this timeframe allows for the inclusion of recent studies that reflect current trends, practices, and challenges, ensuring the review is relevant and up to date. This period also aligns with the growing emphasis on personalised learning and the adoption of AI-driven educational technologies. A study conducted by Guo et al. (2024), also supports the chosen timescale, highlighting important trends identified in the use of AI in education, such as recommender systems, automated grading, intelligent tutoring systems, learning analytics etc., making 2013 to 2023 a critical phase for analysis. For the purpose of conducting an extensive literature search into software applications and frameworks for primary and secondary education, we considered papers published in conference proceedings and scientific journals to explore all peer reviewed manuscripts that are relevant to the study. Also, only papers written in English language were considered as they are within the comprehensive capacity of the authors. Additionally, we verified the search strings on paper titles, keywords and abstracts to ensure that only studies within the SLR criteria were

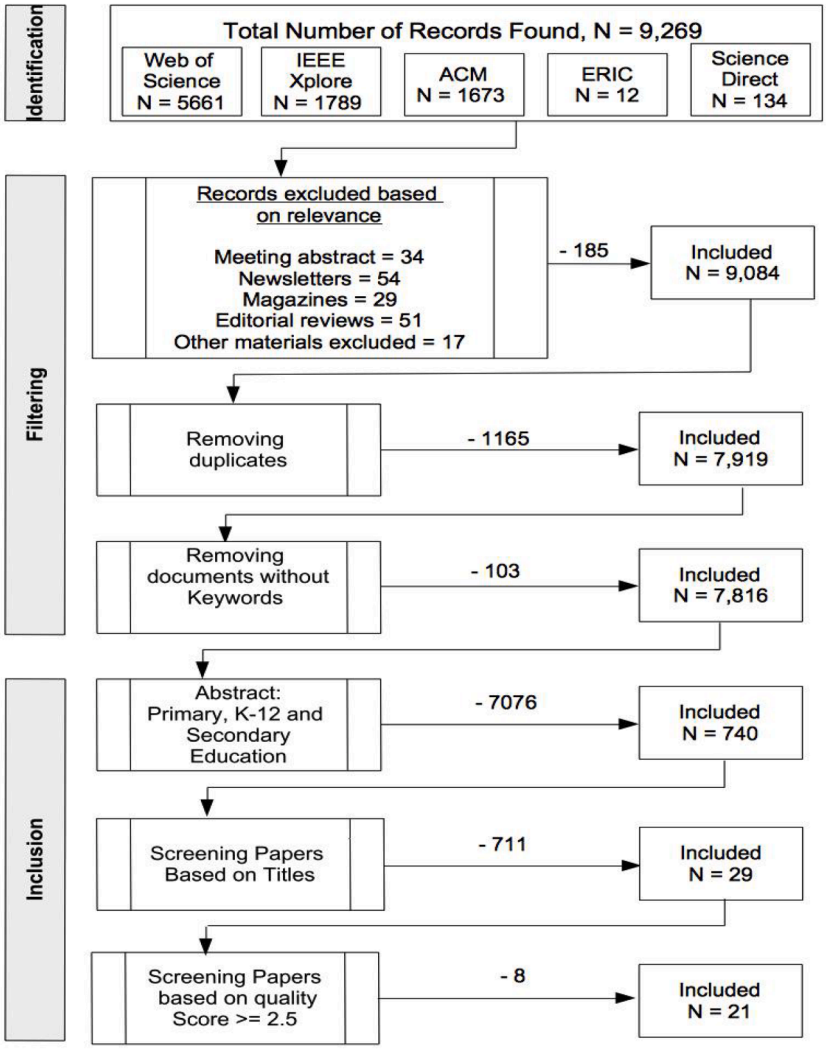

Fig. 2. Flowchart of study selection process.

screened. In contrast, the exclusion criteria clarified that papers that do not fall within the inclusion criteria will be disregarded in the SLR (see Fig. 2).

3.1.5. Defining quality evaluation and study extraction strategy

The next step in the selection process involved evaluating the quality of selected papers. We developed a quality checklist to determine the quality of selected studies based on their relevance to the research questions. The aim of this process was to filter studies that are valid to the context of the SLR and address key considerations that are relevant in the development of software applications for primary and secondary schools. We used the scoring system presented in Campoverde-Molina et al. (2021), that was inspired by Kitchenham and Charters (2007) and assigned a score of 1 if a study showed evidence of addressing the criteria stated in the quality checklist (QC1 to QC5) in Table 4, 0.5 if the study partially shows evidence, and 0 if the study does not address the quality checklist questions. The highest possible score for each study is 5 and papers with a score below 2.5 were eliminated from the final analysis. A total of 29 papers were assessed using the quality checklist. Following this screening, 8 papers were excluded, resulting in a final sample of $N = 21$ papers as seen in Fig. 2.

3.2. Conducting the review

The second phase (conducting the review) was initiated at step 3. Here, we began by conducting searches in five repositories (Web of Science, IEEE, ACM, ERIC and Science Direct) to identify studies that are relevant to software applications used in educational settings. We entered the search strings developed in step 2 into the search engine of each repository and collated the output from each search, which produced a total of $N = 9269$ results as seen in Fig. 2. After this process, we filtered the results to remove duplicates, documents without keywords and materials that are not peer-reviewed, which produced $N = 7816$ papers. In step 4, we selected studies by using inclusion and exclusion criteria (see Table 3). The inclusion criteria were used to identify studies that fell within the scope of the study while the exclusion criteria were used to remove studies that fell outside the scope of the study and did not meet the relevant criteria for evaluation, leaving a total of $N = 29$ papers. After this step, we assessed the quality of each selected study based on their relevance to the research questions and used a scoring technique that adhers to the guidelines presented by Kitchenham and Charters (2007), and only considered studies with a score $>= 2.5$, producing a final selection of $N = 21$ studies. The aim of using the scoring technique was to obtain a reasonable number of primary studies with sufficient depth that fits the scope of the study based on their relevance to each research question. Finally, we extracted the relevant data in step 5 and recorded in a spreadsheet for analyses and reporting in the third phase (reporting) which is presented in Section 4.

Table 3
Study inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
a. Papers published between 2013 and 2023	a. Papers published before 2013
b. Formal papers published in journals or conference proceedings	b. Informal surveys that have not been peer-reviewed.
c. Papers that discuss state-of-the-art techniques that are applicable to software applications in primary and secondary education	c. Papers containing search keywords but from fields that are not relevant to the study (education) will be excluded.
d. Paper must be written in English language	d. Papers that are not written in English language
e. A least one search string should be present in a minimum of one metadata: title, keywords or abstracts	e. Papers that do not contain any of the search strings in their metadata: title, keywords or abstract

Table 4
Quality checklist questions.

ID	Quality Assessment Questions	Answer Yes =1, Partially = 0.5, No = 0
QC1	Does the study present an educational software application/solution for primary and secondary education?	[Yes/Partially/No]
QC2	Does the study highlight the components/ features of the software application used in primary or secondary education?	[Yes/Partially/No]
QC3	Does the study discuss the distinctions between the features of systems used in primary and secondary education?	[Yes/Partially/No]
QC4	Does the study highlight limitations in the adoption of existing educational software solutions?	[Yes/Partially/No]
QC5	Does the study discuss the measurable impacts of existing educational software applications on teaching and learning in primary and secondary education?	[Yes/Partially/No]

3.3. Reporting the review

The third phase (reporting the review) focuses on synthesising and presenting the findings from the selected studies, as well as discussing the broader implications of these findings in the context of primary and secondary education. This phase aims to answer the research questions outlined in the planning phase and provide a comprehensive overview of the current landscape of software applications and frameworks used in educational settings. Further details of our findings and their implications can be found in Section 4.

4. Results

After screening the identified studies, we obtained a final selection of 21 studies which were critically analysed. In the following subsections, we show how these studies helped to answer the research questions posed in this study.

4.1. RQ1: what software applications and frameworks used in primary and secondary education are discussed in literature?

4.1.1. Assessment software

Findings from relevant studies show that the increased use of assessment software applications has revolutionised pupil evaluation by streamlining examinations, grading, and providing feedback to students. Liu et al. (2021) introduces a K-12 classroom evaluation system that is useful to student advisors, course teachers. The system provides relevant functions such as formative learning evaluation, attendance monitoring, and student seating management. A study by Silva et al. (2021) also presents "Vidu Mithuru," an e-learning tool that is capable of evaluating student answers in addition to other functionalities such as auto generating, categorising questions and tracking student performance using artificial intelligence. A significant merit of these tools rests in their ability to provide personalised feedback based on the performance of individual students, helping to identify areas for improvement quickly (Van der Kleij et al., 2015).

4.1.2. Tutoring software

Emerging tutorial software applications, such as Curio SmartChat, which is an AI-powered tool for K-12 learning (Raamadhurai et al., 2019), and the e-learning platform for secondary education (Wijayawardena et al., 2022), present advances in tools that support self-paced learning. These tools showcase attributes such as automated question answering, personalised feedback, and subject-specific assistance, and further enhances learning experiences. Additionally, the BLS Mobile-Based Intelligent Tutoring System presented by Ni and Cheung

(2023) focuses on supporting English learning for secondary students through exercises, self-directed modules, and assessments. The primary merits of these tools rest in their ability to support self-paced learning, making education more accessible and beneficial for students who require more time to grasp concepts.

4.1.3. Authoring software

Authoring tools assist in the creation of educational content. These tools enable the integration of multimedia materials that enhance teaching and learning experience. According to Pender et al. (2022), the concept of a lesson planning software – CLEVER is presented, which supports competency based learining using AI technologies. By using the system, teachers have the ability to easily create personalised learning content for students using blank projects, templates or AI generative features intigrated in the system while considering the curriculim design. In a study conducted by Shymkova et al. (2021), the authors discuss an existing learning management system – ILIAS which is used for developing e-learning materials, managing and diseminating multimedia content in an online educational environment. Ejiri et al. (2015) developed an e-worksheet management system – EWMS that supports the gathering and use of learning materials in primary and secondary schools.

4.1.4. Recommender systems

Recommender systems enhance assessment software by identifying areas where students need improvement and suggests relevant resources. Alonso-Secades et al. (2022) presented the design of a virtual educational system for primary education in developing countries, collecting user activity data to provide tailored recommendations. The system operates in two stages: data collection and data conversion, processing data for analysis. Similarly, Wu et al. (2021) proposed the Mo platform for sharing K-12 educational resources, aimed at providing quality content for AI education. Both systems improve educational outcomes by leveraging intelligent data analysis and resource recommendations.

4.1.5. Simulation software

Technological advancements have now made it possible to experience the world with little to no physical input. In a study conducted by Samanthula et al. (2020), a web-based system is developed for teaching earth and environmental science in middle schools using interactive simulations. Users with adequate internet connection and web browser can access the course and do assignments due to Amazon elastic compute cloud platform. Kaspersen et al. (2021) presented a simulation tool that allows secondary school students to explore and build machine learning models and visualise their societal implications.

4.1.6. Educational games

The landscape of software applications in primary education has seen a significant integration of learning with gamified elements, aiming to engage and excite young learners. A study conducted by Hu et al. (2019) investigates teachers' perceptions of game-based programming tools like FlappyCode and Cargo-Bot, exploring factors influencing teachers' intentions to use these tools in K-12 instruction, with a focus on perceived enjoyment. Similarly, Lee et al. (2014) introduces CTArcade, a web-based educational gaming platform designed to enhance computational thinking skills in young students, using simple games to scaffold complex logic development. In a study conducted by Min et al. (2015) a game-based learning stealth assessment tool is presented, immersing middle school students in a 3D story world to introduce computational thinking. Furthermore, Bolat (2022) emphasizes the utility of gaming tools like Kahoot and Quizizz for formative assessment, highlighting their popularity in creating enjoyable examination materials and quizzes, reflecting the broader trend of leveraging gamification in educational software to foster engaging and effective learning experiences for primary and secondary education.

4.1.7. Other frameworks

From the analysed papers, 3 frameworks were identified which aid adaptive teaching and learning contexts. Chen et al. (2018) introduces the K12EduKG framework, which focuses on the automatic construction of knowledge graphs for K-12 subjects by discerning implicit relationships within educational content of high significance. This framework finds integration within the smart learning partner (SLP) platform, augmenting it by building subject-specific knowledge graphs. Meanwhile, Cosyn et al. (2021) introduces a framework guided by course materials and regular reassessments, rooted in knowledge space theory. This framework serves as the basis for the ALEKS educational software, treating student assessments as probabilistic searches to reveal latent knowledge states. Additionally, Piech et al. (2015) presents a deep knowledge tracing framework leveraging Recurrent Neural Networks (RNNs) to model student knowledge evolution throughout coursework interactions, aiming to predict future student performance accurately. These specialised frameworks showcase advancements tailored for educational contexts, highlighting automated knowledge construction, adaptive learning models, and predictive analytics to enhance teaching and learning experiences in primary and secondary education.

4.2. RQ2: what are the features and components of software applications and frameworks used in primary and secondary education?

4.2.1. Lesson content generation and learning management

The CLEVER system presented by Pender et al. (2022) includes four main components that aid lesson content generation: didactic guidance leveraging AI for personalised learning materials, a recommender system for resources and new content, content management functionalities, and platform services like authentication and user roles. In contrast, the learning management system by Wijayawardena et al. (2022) features an AI chatbot, final grade prediction, and weak area prediction modules, allowing teacher intervention via help tickets. These systems integrate AI, natural language processing, and predictive analytics to enhance educational content and student support.

The Electronic Worksheet Management System (EWMS) presented by Ejiri et al. (2015) supports teachers and students by facilitating e-worksheet creation and modification, managing learning activities, and handling comprehensive data such as timetables and user information. It includes components like a Management Interface for teachers, Rule Analysis for conformity checks, Editing Management for dynamic worksheet construction, Learning Management for teaching and learning oversight, and Database Management for data organisation.

4.2.2. Question answering and tutoring

The Curio Smart Chat system, presented by Raamadhurai et al. (2019), consists of a QA engine, content library, and web-based client. The QA engine refines user queries through spell-checking and normalization, using custom taggers for intent and entity extraction. It employs a Vector Space technique and Universal Sentence Encoder Model for content retrieval, offering quick responses. The system focuses on middle school science, with the content library organised by Bloom's Taxonomy levels to match curriculum requirements.

Ni and Cheung (2023) presented the BLS tutoring system which supports learning through homework, examinations, and self-directed exercises. For vocabulary-related homework, it includes features for vocabulary, reading, writing, and grammar, with AI-generated writing reports. The system uses AI to provide advanced grammar and reading exercises based on student mastery. In examinations, it integrates online assessments with intelligent tutoring, offering AI-generated reports to identify knowledge gaps and provide supplementary training. For self-directed learning, BLS provides a comprehensive database of English exercises for reviewing and mastering various concepts.

4.2.3. Question generation and performance evaluation

In a study conducted by Silva et al. (2021) an AI-based e-learning solution is composed of three integral components, each employing distinct methodologies to support their functions. The first component, the Question Generation and Categorization module, utilizes parts-of-speech analysis to extract answers from PDF documents, generating relevant questions of varying difficulty levels based on a teacher's guide, categorizing them into easy, medium, and hard. The second element, the Descriptive Answer Evaluation module, assesses student responses against sample answers using Natural Language Processing (NLP) techniques, assigning scores based on similarity percentages obtained through semantic comparison. The third segment, the Emotion Detection module, employs neural networks to analyse students' verbal and facial expressions, capturing emotions using speech command collection and facial expression analysis, showcasing motivational quotes on screen based on detected emotions.

4.2.4. Collaboration and resource sharing

The web-based platform proposed by Wu et al. (2021) includes five key components: an online learning environment, sharing and community support, crowdsourcing educational resources, exercise and evaluation support, and playful experimentation. It uses JupyterLab for the front end and a customised JupyterHub for the backend. The platform supports collaboration through features like presentation mode, video streaming, and collaborative tools, enabling idea and resource sharing in AI communities. It facilitates crowdsourcing of materials such as textbooks and exercises from teachers. Additionally, it provides various exercises and automated assessments for efficient student evaluation. A playful experiments portal helps students with limited programming experience engage with AI applications, fostering critical thinking and problem-solving skills.

4.2.5. Formative assessment and auto-grading

The classroom evaluation system by Liu et al. (2021) consists of three main components: the user interface layer, business logic layer, and data access layer. The user interface layer ensures a user-friendly experience with a visually appealing design optimised for mobile devices. The business logic layer includes features for formative assessment, seating and attendance management, and classroom performance tracking. The data access layer maintains records for classroom facilities and personnel, along with a formative assessment database for tracking student progress.

The ACMES system by Samanthula et al. (2020) utilises web database technologies on AWS and includes modules for authentication, user roles, and auto grading. The authentication layer secures access using SSL certificates and encryption, while user roles provide different functionalities for guests, students, teachers, and administrators, enabling access to simulations, lessons, assessments, and administrative tasks.

4.2.6. Activity recommendation

Alonso-Secades et al. (2022) proposed a recommender system with four key components: data warehousing, analytical data processing, monitoring processes, and recommender systems. The data warehousing component collects and stores data from 40 countries in the ProFuturo foundation project, using MongoDB for unstructured data and SQL server for structured data. Analytical data processing uses machine learning to identify patterns in students' knowledge, facilitating personalised teaching. The monitoring process tracks system usage and student behaviour, such as activity duration and completion rates, to improve pedagogical strategies. The recommender systems component provides recommendations to students, teachers, and educational centres based on these insights to enhance teaching and learning practices.

4.3. RQ3: what are the distinctions between the features of systems used in primary and those used in secondary education?

The distinctions between the features of systems used in primary and secondary schools are based on factors such as learning objectives, curriculum and the age group of students. Some common distinctions evident in literature are highlighted below.

4.3.1. Complexity and depth

The features of software applications used in primary education tend to have simplified contents and interface that can cater to the cognitive abilities of younger age groups. In a study conducted by Pender et al. (2022), some of the operations of the proposed system include uploading lesson contents from external sources, choosing lesson recommendations suggested in CLEVER system library, creating new lesson elements using AI generated templates and exporting lesson contents for both digital and in-classroom lessons.

On the other hand, software applications for secondary education tend to offer more in-depth and advanced features that meet the needs of older students. For instance, the main features of the system proposed for secondary education by Wijayawardena et al. (2022) were centred about AI tutorials, predicting the final grade of students and predicting students' weak areas for to ensure that adequate plans are set in place towards helping students to improve.

4.3.2. Interactivity and engagement

Software applications for primary education also include visually stimulating and engaging elements that aim to make learning more enjoyable for younger students. In a study conducted by Silva et al. (2021), the proposed mobile application auto-generates questions and allows students to make multiple attempts whilst evaluating student answers and displaying motivational quotes to encourage students that are struggling using an emotion detection model.

On the other hand, software applications used in secondary schools prioritise deeper engagements through simulations, lab activities, and other interactive activities to enhance students' understanding of complex concepts. For instance, Samanthula et al. (2020) proposed an interactive tool that enables teachers to effectively teach earth and environmental science using interactive simulations.

4.3.3. Assessment and feedback

Assessments in software tools used in primary schools focus more on games, quizzes and learning activities that provide quick feedback as seen in studies conducted by Liu et al. (2021), Silva et al. (2021). While software applications used in secondary schools tend to focus more on sophisticated assessment tools such as progress tracking, examinations and essay evaluations (Wijayawardena et al., 2022; Hasib et al., 2022; Sokkhey & Okazaki, 2020).

4.3.4. Collaboration and group work

Software applications used in primary schools show more emphasis on individual learning and skill development (Silva et al., 2021), while collaborative features such as group projects and discussion forums are relevant to software applications used in secondary schools. For instance, Kaspersen et al. (2021) presented a system that enables collaborative development, evaluation and reflection on machine learning models in secondary schools.

4.4. RQ4: what limitations in the adoption of existing educational software solutions for primary and secondary education are discussed in literature?

According to research, the perceptions and adoption of educational software applications in independent learning settings are influenced by factors such self-efficacy and technology anxiety. For instance, Abdullah et al. (2016) emphasises the significance of self-efficacy, indicating its

impact on how users perceive the ease of use and usefulness of software applications. Similarly, Zheng and Li (2020) specifically notes how the self-efficacy of middle school students influences their perceptions of tablet devices' ease of use and usefulness. Moreover, technology anxiety, describes users' discomfort with teaching and learning applications, and this poses a hurdle to the adoption of tools like Intelligent Tutoring Systems (Ni & Cheung, 2023) in the case of learners. This anxiety leads to hesitancy in utilising these systems, impacting students' confidence in their ability to perform effectively.

These findings are supported by recent literature. For instance, Huang and Wang (2022) explored the impact of self-efficacy on students' acceptance of e-learning platforms, demonstrating that higher self-efficacy leads to greater perceived ease of use and usefulness, which in turn enhances user acceptance and engagement. In addition, a study by Li et al. (2023) also addresses technology anxiety, revealing that it significantly hinders the adoption of mobile learning applications among users. They argue that reducing technology anxiety through targeted interventions, such as training programs and user-friendly designs, can significantly improve the adoption rates of these technologies.

A study by Bower et al. (2020) also shows that the high deployment costs of advanced technologies like virtual reality also hinders their broad-scale implementation in teaching and learning. Moreover, for tools such as Intelligent Tutoring Systems (ITS), the perceived advantages in comparison to their costs significantly influences user intentions (Ni & Cheung, 2023). Research conducted by Mehta et al. (2019) and Alghazi et al. (2021) emphasise the pivotal role of price value in shaping user acceptance and perceived usefulness of mobile and e-learning applications. Cost-related challenges extend beyond technology to include resource accessibility and school budget constraints, as indicated in CooperGibson Reasearch (2018), impacting the availability of high-quality resources in primary and secondary schools. Additionally, Wu et al. (2021) identifies challenges in integrating AI education into K-12 settings, citing difficulties in adapting university-level AI learning pathways and the practical requirements, which demand substantial computational resources that are not easily accessible in primary and secondary schools.

4.5. RQ5: what are the measurable impacts of existing educational software applications on teaching and learning in primary and secondary education?

In a study conducted by Raamadhurai et al. (2019), the proposed software application possesses the capability of engaging students through both content-based and off-topic conversations. Given the scope of the system, analyses of user queries focused on spelling mistakes, validity of recommendations and off topic chats. The results showed that 60 % of recommendations generated by the system were relevant to user queries, therefore saving time for both teachers and students.

Case studies were conducted by Wu et al. (2021) to assess the impact of the proposed recommender platform – Mo after trials in offline and online classrooms. Overall, 82 % of students said that the platform helped to improve their performance in the classroom. 75 % of students and 86 % of teachers advised that the platform could provide them with quality educational resources and improve their experience through communication with senior teachers over the system.

Overall, over 80 % of respondents indicated that the simplicity of the classroom evaluation system presented by Liu et al. (2021) could facilitate classroom teaching, with 93 % of respondents showing satisfaction with the aesthetic and interactive design of the system interface. Overall, 52 % of respondents suggested that the system assists in improving the efficiency of formative assessments in classrooms.

From the analysed studies, Hu et al. (2019), deployed a 15-item questionnaire to a total of 30 teachers in elementary and secondary schools in China to evaluate their perceptions on the use of game-based programming tools (GBPTs) such as Flappy code, light-bot, run marco and cargo-bot in K-12 classrooms. Overall, 64 % of respondents indicated that GBPTs are beneficial for improving programming learning. Analysis of open-ended suggestions from respondents also indicated that various factors would improve the usability of GBPTs such as providing guidance and professional training for teachers, providing supplementary learning materials for teacher development, incorporating hints and conclusions in the GBPT interface.

5. Discussion

The comprehensive analysis of 21 selected studies on educational software applications and frameworks for primary and secondary education reveals both the potential benefits and inherent challenges of these technologies. Our findings reveal a diverse range of tools designed to enhance various aspects of the educational experience, including assessment, tutoring, content creation, recommendation, simulation, and gamification.

Our findings indicate that assessment software significantly enhances the efficiency and accuracy of student evaluations. Liu et al. (2021) and Silva et al. (2021) highlight tools that facilitate formative evaluations and track student performance effectively. These findings align with Leacock and Nesbit (2007), who emphasise the value of automated assessments in providing timely feedback. However, some researchers argue that over-reliance on automated systems can undermine the role of teacher judgment. For instance, Bennett (2011) contends that while technology can assist in assessments, it should not replace the nuanced understanding that teachers bring to evaluating student progress.

The role of AI in tutoring software, such as Curio SmartChat and the BLS Mobile-Based Intelligent Tutoring System, is highlighted for its ability to provide personalised learning experiences (Raamadhurai et al., 2019; Ni & Cheung, 2023). However, Selwyn (2016) cautions against the overreliance on AI, arguing that it may reduce the human element essential in education. He suggests that the social and emotional aspects of learning, which are crucial for holistic development, might be neglected in AI-driven environments. A study conducted by VanLehn's (2011) also argued that the ITS could be used to effectively replace homework activities and other in a classroom related tasks but should not be used to replace the entire classroom experience. Tools such as CLEVER and ILIAS also allow educators to create personalised content efficiently (Pender et al., 2022; Shymkova et al.,2021). However, concerns regarding the accessibility and usability of these tools for all educators have been raised in the research community. For instance, Koehler and Mishra (2009) points out that teachers need adequate training to effectively use these technologies, and without proper support, the potential benefits of authoring software may not be fully realised.

Findings from this study supports a study conducted by Valverde-Berrocoso et al. (2022), which showed that the distinction between tools designed for primary and secondary education is evident, with primary education software focusing on simplicity and engagement, while software used in secondary schools offer advanced features for deeper learning. This differentiation is crucial for meeting the distinct needs of different age groups, although there is an argument that such segmentation might limit the flexibility of educational tools. A study conducted by Shute and Rahimi (2017) propose that more adaptable tools could serve a broader range of educational needs, fostering continuous learning across different educational stages.

The analysis also identifies barriers such as self-efficacy and technology anxiety, which can hinder the adoption of educational software among other barriers. Studies conducted by Abdullah et al. (2016) and Zheng and Li (2020) highlighted some of these issues. However, some argue that these barriers can be overcome with proper training and support. For instance, Hew and Brush (2007) suggest that professional development and a supportive school environment can significantly mitigate these challenges, enabling teachers to effectively integrate technology into their classrooms.

6. Limitations

While this study provides a comprehensive analysis of educational software applications and frameworks for primary and secondary education, it is important to acknowledge several limitations that may affect the generalisability and interpretation of the findings.

The systematic literature review is based on a selection of 21 studies, which, although diverse, may not capture the entire spectrum of available educational software and their impacts due to a limited number of primary studies that analyse existing software applications used in primary and secondary schools. The limited number of studies might introduce some bias, potentially overlooking significant tools or perspectives not covered in the academic literature. This SLR identifies software applications that enable personalisation of teaching and learning content. However, the impact of existing educational software on diverse student populations, including those with special educational needs, is not thoroughly examined in this SLR.

7. Conclusion

The evidence obtained in this paper are based on primary studies published over a period of 10 years (2013 to 2023). This study presented an overview of software applications for primary and secondary education which can support leaders and practitioners in understanding the types of educational tools available and important considerations to take into account in the adoption and use of these tools.

Among the selected studies, an enquiry into the types of software solutions and frameworks showed that the range of software applications for primary and secondary education discussed in literature are from assessment software applications to intelligent tutoring systems. With respect to the features and components of software applications used in primary and secondary education, a range of features were identified that support aspects of teaching and learning such as lesson planning, lesson delivery, classroom management, assessment and self-directed learning, which supports a study conducted by the DfE (Shearing, 2023) showing the relevance of advance AI features in automating tasks and reducing teacher workload. Based on these features, some distinctions between the tools used in primary and secondary schools were further discussed which showed their differences based on complexity and depth, interactivity and engagement, assessment and feedback, and collaboration. Evidence from selected studies also showed that factors such as high costs associated with deploying software solutions, users' self-efficacy and technology anxiety can affect the adoption of new technologies in primary and secondary educational settings.

The trajectory of this study aims to enhance understanding of educational software applications and contribute to the informed design and adoption of these tools to improve learning outcomes in primary and secondary education. The integration of educational software in primary and secondary education presents both significant opportunities and challenges. The theoretical implications of our findings provide a framework for understanding the complex dynamics of educational technology, whereas the practical implications offer a roadmap for its effective implementation and use. As educational technology continues to evolve, it is imperative that educators, policymakers, and technology developers work collaboratively to harness its potential, ensuring that it complements traditional pedagogical practices and addresses the diverse needs of all students. Through balanced and informed application, educational software can significantly enhance the learning experience, paving the way for a more dynamic and inclusive educational landscape.

Based on our findings, several avenues for future research is recommended; Future research should focus on longitudinal studies to assess the long-term impact of educational software on student learning outcomes, teacher effectiveness, and overall classroom dynamics. These studies can provide deeper insights into the sustainability and evolving benefits of technology integration in education. Investigating the effectiveness of various teacher training programs in equipping educators with the necessary skills to use educational technologies effectively is crucial. Comparative studies could identify best practices and inform the development of more targeted professional development initiatives for teachers to enable them to properly adapt to the new technological landscapes. In addition, investigating strategies to overcome barriers such as self-efficacy and technology anxiety remains a critical area of research. Studies could also evaluate the impact of various support mechanisms, including peer mentoring, technical support, and community building among educators.

CRediT authorship contribution statement

Benjamin Agbo: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ceris Morris:** Investigation, Methodology, Conceptualization, Writing – review & editing. **Mogdam Osman:** Writing – review & editing, Methodology. **Joe Basketts:** Writing – review & editing, Validation, Investigation. **Theocharis Kyriacou:** Supervision, Methodology, Conceptualization, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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