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A Review of Solutions to Assist Novice Programming Students in Africa

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Abstract
This study explores the landscape of initiatives aimed at supporting novice programming students with a focus on Africa, where challenges in accessing quality instructional materials and resources persist. Drawing from a scoping review methodology, this study analysed 37 articles from various continents to assess the solutions offered and Africa's contribution to the body of literature. The findings revealed a diverse array of solutions, including augmented reality, chatbots, instructional frameworks, educational games, and specialised tools for progress evaluation. While the United States and Japan lead in contributions, Africa shows growing engagement primarily represented by South Africa and Mauritius. However, broader collaboration and inclusivity among researchers from diverse regions have been emphasised to advance the field globally. This study emphasises the importance of addressing the challenges faced by novice programmers through innovative pedagogical strategies and emerging technologies to ensure equitable access to programming education worldwide. Furthermore, this study found that it would be beneficial for these technologies to be adjusted to become compatible with inexpensive mobile devices, enabling engaging experiences even in regions with insufficient infrastructure. Future research should include wider geographical coverage and incorporate qualitative methods to enrich understanding and promote collaborative programming initiatives.

Keywords: Novice programming students, Africa, Tools, and educational solutions.

1. Introduction

Numerous tools have been created to assist inexperienced and novice programmers in acquiring programming skills. Nevertheless, delivering adequate support to students remains a challenge (Prather et al., 2023). Novice programmers encounter substantial challenges in learning key coding skills, particularly in areas with limited access to high-quality instructional materials. This is evident in regions, such as Africa. Africa's contribution to supporting novice programming students is rather restricted compared to regions that have well-developed tech education ecosystems (Boateng et al., 2021). This lack can be attributed to the scarcity of software developers in Africa. According to the "e-Conomy Africa 2020" report by the International Finance Corporation (IFC) and Google, there are 700,000 software developers in Africa, with more than half of them in Egypt, Kenya, Morocco, Nigeria, and South Africa (Buckholtz & Oloo, 2020). This number is extremely low compared to the 26.3 million global count of software developers reported by CodeNinja (2023), meaning that Africa has only produced 2.68% of the global software developer population. The global demand for software developers is projected to reach more than 28.7 million by 2024, necessitating the need to support novice programming students in Africa (CodeNinja, 2023).

Africa has a significantly lower rate of digital literacy than other regions (Boateng et al., 2021). Limited access to essential resources such as the Internet, electricity, and computers remains a challenge in Africa (Zhampeissova et al., 2020). According to Krönke (2020), Afrobarometer's 2016-2018 study of 34 African countries found that people still do not have easy access to devices such as computers and cell phones, about 11% of families did not have either a cell phone or a computer, and 43% also had only basic cell phones that could not connect to the Internet. Furthermore, inadequate infrastructure, lack of exposure to new coding tools, and scarcity of localised, beginner-friendly content often

contribute to the existing divide in programming education (Zhampeissova et al., 2020).

The African context is particularly important because of its demographic dynamics and urgent need for a skilled workforce to support economic growth. The continent is experiencing rapid population growth, which necessitates significant investment in education, especially in technology and programming (Kebede et al., 2019). This investment is crucial not only for individual empowerment but also for creating the human capital required for sustainable development. The challenges faced in programming education, such as inadequate ICT resources and teacher training, are echoed in broader educational challenges across the continent (Egbai et al., 2021). Addressing these issues is vital to ensuring that Africa can compete in the global digital economy. Moreover, Africa's unique socio-cultural landscape necessitates a tailored approach to programming education. The integration of local languages and culturally relevant content can enhance engagement and effectiveness in learning (Ball et al., 2024). This is particularly relevant in the context of bilingual education programs, where the quality of education can be significantly impacted by sociocultural perceptions of local languages (Ball et al., 2024). Consequently, numerous aspiring programmers have constrained educational journeys, which hinders their ability to make meaningful contributions to the rapidly evolving digital ecosystem (Boateng & Kumbol, 2018).

Due to the above-mentioned challenges, African leaders are increasingly advocating for the expansion of computer and programming education. This effort aims to overcome barriers to digitalisation and ultimately improve the African economy by equipping more people with the necessary skills to participate in the digital world (Langthaler & Bazafkan, 2020). In addition, Mbogo et al. (2016) states that there is a need to investigate what has been done in the literature to support novice programmers in an African context. As such, this study aims to explore the initiatives undertaken in Africa to support novice-programming students by conducting a scoping review. This study contributes to the body of knowledge by summarising interventions that have been conducted in Africa to assist novice student programmers in programming modules and further provides a path for future research in addressing the issue at hand in the context of Africa.

Furthermore, this study serves as a valuable resource for researchers who aim to advance programming education in Africa. It offers a comprehensive understanding of current efforts and provides a roadmap for future research. By focusing on the African context, this study ensures its relevance and offers valuable insights for tailoring educational frameworks and informing policy development. Researchers can use these findings to build on the existing knowledge and contribute to enhancing programming education in similar settings.

2. Literature review

2.1. Computer programming and novice programmers

The core components of any programming language,namely syntax and semantics, are frequently identified as the primary contributors to the challenges encountered in the early stages of programming (Ullah et al., 2018). Novice programmers frequently encounter challenges in producing high-quality codes, despite having acquired knowledge of the syntax and semantics of the programming language (Malik et al., 2021).

The nature of programming requires the cultivation of a comprehensive skill set, such as the capacity to develop and debug programmers, problem solving, and analytical reasoning. A significant challenge for novice programmers is that they are expected to master all of these techniques simultaneously (Malik et al., 2022; Malik et al., 2021). Cheah (2020) points out that novice student programmers often face a common challenge characterized by a deficiency in problem-solving skills related to problem analysis and a limited understanding of programming concepts.

Most novice programmers lack the essential cognitive abilities of critical thinking and problem solving that are required to acquire computer programming knowledge (Djambong & Freiman, 2016; Ubaidullah et al., 2021). As a result, they find programming to be difficult. For most students, the challenging nature of learning to code is strongly influenced by various dimensions of knowledge, including conceptual and procedural knowledge, as well as multiple cognitive processes, including understanding, analysing, and evaluating (Hobert, 2019).

Students face difficulties in understanding abstract programming concepts such as control structures and formulating algorithms to solve specific problems (Cheah, 2020). Inadequate knowledge consolidation and illogical reasoning are additional factors that worsen learning challenges among novice programmers (Savage & Piwek, 2019). They also face challenges in writing effective functions and procedures due to limited comprehension of fundamental programming language features, including variables, arrays, recursion, and loops, during the initial stages of their learning process (Cheah, 2020).

These challenges are magnified in the African context because of the scarcity of technology-learning resources and infrastructure. Limited access to educational resources and technology impedes the development of programming skills, thereby worsening the difficulties faced by students in the learning process (Zhampeissova et al., 2020). Moreover, educational experiences and results are shaped by cultural factors. Students' interactions with programming instruction may change, depending on their conventional ideas and habits. Cultural views towards technology and education, for instance, can result in gender discrepancies in Science, Technology, Engineering, and Mathematics (STEM) disciplines, where girls become less encouraged to pursue technical topics (Calitz et al., 2020; Olayemi & DeBoer, 2021). Furthermore, there is a shortage of culturally appropriate material in the curriculum, which results in students being discouraged if their cultural backgrounds are not reflected in their education (Zimu-Biyela, 2019).

2.3. Benefits of supporting novice students

Programmers have become an integral part of the driving forces of technological ecosystems. The growing advancement of technology has increased the demand for professionals with programming skills (Hobert, 2019); however, there is often a shortage of qualified professionals. By supporting novice programmers, we can help address this skill gap and ensure that there are enough skilled individuals to meet the needs of the digital workplace. The lack of adequate resources in Africa, as highlighted by Zhampeissova et al. (2020), has had a significant impact on novice programmers. Providing access to programming education and resources will create opportunities for students to pursue careers in technology and contribute their unique perspectives to the field. This access also contributes to the process of learning programming for novices, thereby improving overall performance (Shi et al., 2017).

Supporting novice programming students in the early stages enables them to improve their coding skills which eventually contributes to the success of producing programmers that will form part of the skilled workforce in the ecosystem (Ahmed et al., 2020). According to Zha et al. (2023) through the support, novice programmers develop problem-solving abilities as well as logical and computational thinking skills that are valuable in various aspects of life and work.

According to Ullah et al. (2018), increased participation and learning encourages and motivates novice programmers when they feel supported. This often brings fresh perspectives and innovative ideas to the table (Ullah et al., 2018). Supporting novice programmers will encourage creativity and innovation within the field, leading to the development of innovative software solutions, applications, and technologies that drive progress and economic growth, and further contribute to the continuous evolution of software development (Marwan et al., 2019).

This will enable them to adapt to technological advancements and eventually inspire innovation.
Investing in programming education and resources for novice programmers is essential for creating a thriving and dynamic technology sector that positively impacts both the economy and society (Marwan et al., 2019).
This study aims to help policymakers and curriculum designers craft informed strategies that will strengthen educational infrastructure and capacity, foster the development of a skilled workforce, fuel economic growth, and enhance global competitiveness.

3. Methodology

To provide an overview of scholarly work done in Africa to support novice programming students and to fulfil the objectives of this study, a scoping review was conducted following the guidelines of Kastner et al. (2012); Petersen et al. (2008) which include: identifying the research question(s), formulating the search strategy, study selection, and extraction of data. According to Pollock et al. (2022), the purpose of a scoping review is to provide a comprehensive and systematic overview of the existing literature on a broad research topic, to help researchers map key

concepts, identify gaps in the literature, and clarify the scope of a particular field or subject.

3.1 Research questions

The purpose of this research is to conduct a scoping review to summarise what scholarly research has been conducted in Africa to assist novice programming students by addressing the following research questions:

RQ1: What solutions have been offered in literature to support novice programming students?

RQ2: To what degree has Africa contributed to the literature supporting novice programming students?

3.2 Search Strategy

Six electronic databases were used for this study: SCOPUS, IEEE Xplore, ACM Digital Library, Sabinet African Journals, Taylor & Francis Online, and Wiley Online Library, since they were easily accessible to researchers and for their vast publications from reputable journals. Sabinet African Journals, and Taylor & Francis (African Journal of Science, Technology, Innovation, and Development) were specifically chosen for their publication in African studies.

The combination of keywords used to formulate the search strings included ("Tools" OR "solutions") to ("assist" OR "support" OR "help") and ("novice" OR "beginner") and (programming" OR "coding") and ("students" OR "learners"). Search strings were constructed to minimise the possibility of leaving out relevant literature in relation to the study.

3.3 Study selection

The search and screening of articles for selection was performed in accordance with the inclusion and exclusion criteria described in Table 1. The selection process used in this study is summarised in Figure 1.

Database searches conducted in December 2023 resulted in 746 articles, including duplicates. A total of 197 articles were from the ACM Digital Library, 37 from Wiley Online Library, 500 from IEEE Xplore, 209 from SCOPUS, 0 from Sabinet African Journals, and 0 from Taylor & Francis.

Table 1: Inclusion and exclusion criteria.

Inclusion of articles	Exclusion of articles
Articles were peer reviewed	Articles not peer reviewed
Articles provided solution to assist novice programming students	Articles not written in English
Articles were published between 2000 and 2023	Did not provide a solution to assist novice programming students
Articles written in English	Outside the year range 2000 to 2023
	Abstract only

The researchers used an open-source reference management tool called JabRef to remove duplicates from the total articles, after which 733 articles remained for further screening. The articles were further screened by title to determine if they were relevant to the topic at hand, of which 114 were included in the next phase of screening. Of the 114 articles screened by abstract, only 41 remained. The articles were further screened by full text and only 33 remained. The researchers conducted forward and backward searches and identified seven additional articles. Only four of the seven articles passed the full inclusion and exclusion criteria. The total number of studies that were selected for data extraction was 37.

3.4 Data extraction

In this study, 37 articles were selected, and JabRef was used to arrange the articles and extract data. The retrieved data were carefully arranged and saved in a Microsoft Excel spreadsheet for further examination. The data and their contents are elaborated in the subsequent section. The extracted data included author names, author location, title, year, and the proposed solution or tool. Furthermore, the proposed solutions were categorised to reveal the type of solutions prevalent in addressing the issue at hand.

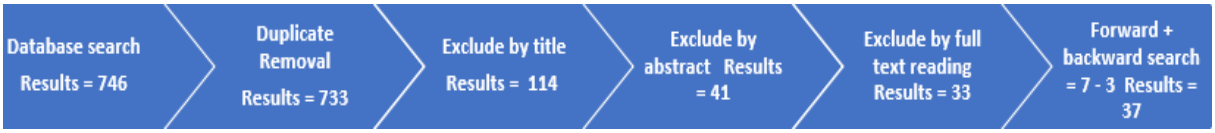

Figure 1: This study's selection process

4. Results

The findings of the analysis of the data retrieved from the 37 articles are presented in this section following the guidelines of Petersen et al. (2008) for analysing systematic mapping studies.

4.1 Solutions offered to support novice programming students

The succeeding discussion is aimed at addressing RQ1: "What solutions have been offered in literature to support novice programming students?" by providing a summary of what has been done on the topic at hand. The frequency of publications from studies included in this study per country is displayed in Table 2 and graphically represented in Figure 2. The United States had the most publications on assisting novice programming students, with a frequency of eight publications, followed by Japan with seven publications. Taiwan, South Africa, and India came in third place, with three publications each. China published two studies, and the countries with the least publications were Sri Lanka, Singapore, Portugal, Pakistan, New Zealand, Mauritius, Malaysia, Indonesia, and Ireland, each with one publication. Furthermore, there were studies that collaborated from different countries, such as China and Portugal, and a collaboration between Botswana, Nigeria, and the UK.

Table 1. Frequency of publication by country

Country	References	Frequency
USA	(Flowers et al., 2004; Hassan & Hill, 2018; Henley et al., 2021; Lee & Ko, 2016; Marwan et al., 2022; Stein & Lédeczi, 2021; Tan et al., 2022; Zhao et al., 2022)	8
Japan	(Abe et al., 2019; Aung et al., 2022; Funabiki et al., 2012; Funabiki et al., 2015; Lu et al., 2022; Phuong et al., 2009; Tamada et al., 2011)	7
India	(More et al., 2011; Sajana et al., 2015; Venigalla et al., 2019)	3
South Africa	(Ismail & Ade-Ibijola, 2019; Mbogo et al., 2013; Okonkwo & Ade-Ibijola, 2020)	3
Taiwan	(Lin, 2022; Lin & Tsai, 2019; Teng & Chen, 2012)	3
China	(Li et al., 2020; Zhang et al., 2021)	2
Botswana, Nigeria, and UK	(Tshukudu et al., 2022)	1
Indonesia	(Sukamto & Megasari, 2017)	1
Ireland	(Liu, 2018)	1
Malaysia	(Using et al., 2010)	1
Mauritius	(Hosanee & Panchoo, 2015)	1
New Zealand	(Hu et al., 2021)	1
Pakistan	(Zafar & Farooq, 2019)	1
Portugal	(Carreira et al., 2022)	1
Portugal and China	(Gomes et al., 2019)	1
Singapore	(Duong et al., 2022)	1
Sri Lanka	(Li et al., 2020; Zhang et al., 2021)	1

The selected studies were further analysed to reveal what type of solutions were offered in the selected studies, as seen in Table 3 which maps the studies to the solutions they offer. The solutions were categorised as augmented reality (AR), in which one publication presented an AR environment for students to visually learn programming concepts; chatbot, whereby five publications developed chat bots that can answer programming questions and explain concepts in a way that is easier for students to understand. Other listed categories include code generator by one publication, which generates visuals to aid students in understanding programming concepts visually; framework, whereby three publications presented guidelines that make learning programming easier; and game, in which two publications created interactive games for learning coding.

An Integrated Development Environment is another category in which one publication developed an IDE that helps students easily grasp variable definitions and include statements. Furthermore, the metaphoric representation of concepts is another identified category. In this category, coding concepts are explained metaphorically as demonstrated in a single study. The Plugin category includes API extensions and provides rapid programming advice. These were created in 3 publications. Tools for e-assessment, feedback creation, Java statement comments, and an adaptive rapid feedback system for encouraging students during programming sessions fall under the progress evaluation category seen in five publications.

Solutions under the Self-study assistant application category automatically assessed and corrected students' work during their study. This was evident in 11 publications. For the Simulation category 1 study, a simulator was created to allow students to operate their own robots and collaborate in a 3D virtual environment. Visualisation of concepts, visible in two publications, is a category in which basic programming logic is taught using analogy mapping to accommodate different learning styles. Finally, one publication created a workshop to educate novice programmers.

Table 2. Frequency of solutions published

Solution	References	Frequency
Self-study assistant	(Amaratunga et al., 2013; Aung et al., 2022; Flowers et al., 2004; Funabiki et al., 2012; Funabiki et al., 2015; Liu, 2018; Lu et al., 2022; Mbogo et al., 2013; More et al., 2011; Phuong et al., 2009; Using et al., 2010)	11
Chat-bot	(Carreira et al., 2022; Ismail & Ade-Ibijola, 2019; Lin, 2022; Lin & Tsai, 2019; Okonkwo & Ade-Ibijola, 2020)	5
Progress evaluation	(Duong et al., 2022; Hassan & Hill, 2018; Hosanee & Panchoo, 2015; Li et al., 2020; Marwan et al., 2022)	5
Framework	(Tamada et al., 2011; Tan et al., 2022; Zhang et al., 2021)	3
Plugin	(Henley et al., 2021; Venigalla et al., 2019; Zhao et al., 2022)	3
Game	(Lee & Ko, 2016; Sajana et al., 2015)	2
Visual representation of concepts	(Hu et al., 2021; Sukamto & Megasari, 2017)	2
Augmented reality	(Teng & Chen, 2012)	1
Code generator	(Zafar & Farooq, 2019)	1
Integrated Development Environment	(Abe et al., 2019)	1
Metaphoric representation of concepts	(Gomes et al., 2019)	1
Simulation	Stein and Lédeczi (2021)	1
Workshop	Tshukudu et al. (2022)	1

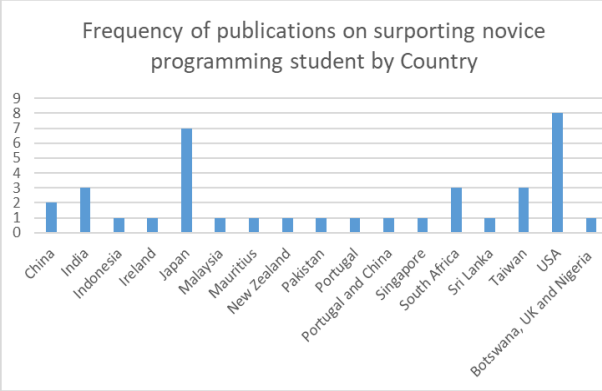

Figure 2. Frequency of publications by country

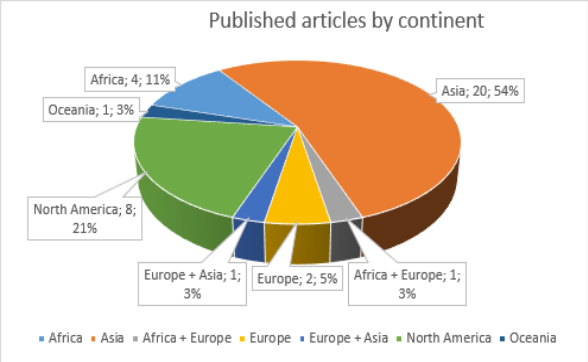

Figure 3. Publications on supporting novice programming students by continent

4.2 Africa's contribution to assisting novice programming students

To address the second research question labelled as RQ2: "To what degree has Africa contributed to literature for supporting novice programming students?" The researchers examined what has been done on other continents from the extracted data on the topic compared to the African continent. The findings of this study are shown in Figure 3.

To determine the degree to which Africa has contributed to the body of knowledge in supporting novice programming students, this study examined what other continents have published on the matter in comparison with Africa, as depicted in Figure 3. The results showed that Asia was the biggest contributor to the topic at hand, with 54% (20 out of 37) of publications from the included studies. This is followed by North America, with a 21% (8 out of 37) publication rate. Africa was the 3rd largest contributor, with 11% (4 out of 37) of publications. Europe and Oceania trailed behind with 5% (2 out of 37) and 3% (1 out of 37), respectively. These findings indicate the scarcity of collaborative cross-continent studies. Only one publication (3%) involved collaboration between Africa and Europe, and the same holds true for the collaboration between Asia and Europe.

Figure 4 displays the number of countries that have contributed to the topic by continent for the selected studies. The results show that Asia has more countries (9) engaged compared to other continents. Interestingly, North America, which is the second largest contributor in publications, has studies coming from only one country (USA); however, this could be due to the umbrella of the United States, which has numerous countries subscribed under it. Based on this study's analysis, Africa has only two countries (South Africa and Mauritius) that have published on the matter. Even though the study by Tshukudu et al. (2022) has authors from Africa, it cannot be fully attributed to Africa, as it collaborates with Europe. Europe has only two countries (Ireland and Portugal). Oceania (New Zealand) was the continent with the least contribution.

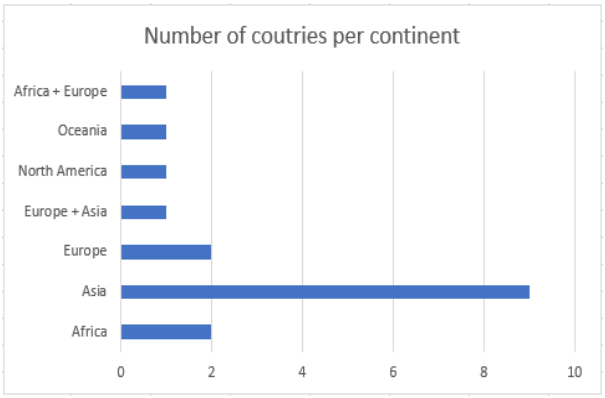

Figure 4. Countries per continent

5. Discussion

The analysis of 37 articles focused on assisting novice programming students offers detailed insight into the worldwide landscape of this field. The United States emerged as the primary contributor, with 21.6% of publications closely trailed by Japan (18.9%), signifying significant contributions from North America and Asia. In contrast, Africa and Europe exhibit limited participation, with South Africa and Mauritius representing Africa and Ireland and Portugal representing Europe. Oceania, represented solely by New Zealand, demonstrated the least involvement, indicating a minor presence in global research on this topic. However, there has been a noticeable rise in Africa's engagement in supporting novice programming students with growing enthusiasm for promoting programming

education across the continent. This trend is evident in studies such as Tshukudu et al. (2022), where African countries such as Botswana and Nigeria collaborate with the UK in educational initiatives such as the Africa Code Week.

The solutions offered in the literature encompass a diverse range of approaches, including cutting-edge technologies such as augmented reality and chatbots, instructional frameworks, educational games, and specialised tools for progress evaluation. The inclusion of metaphoric representations, self-study assistant applications, simulations, and visualisation techniques reflects a dynamic and innovative response to the challenges faced by novice programmers. The purpose of these integrations is to make programming education more accessible and to provide a variety of learning options for beginner programmers. Additionally, the prevalence of self-study assistance, progress evaluation, and chatbot solutions can be attributed to their use of machine learning and natural language processing, which provides students with individualised explanations and feedback. These tools promote self-directed learning by providing on-demand support through the simulation of human interaction. Examples such as IPO Chatbots and PythonBot show the potential of AI-driven conversational agents in aiding programming analysis and simplifying learning programming by novice students. These findings are consistent with observations made by Hasan et al. (2020).

The diverse array of solutions presented in the selected studies underlines the importance of adopting a multifaceted approach to addressing the challenges faced by novice programmers. By leveraging emerging technologies and innovative pedagogical strategies, educators and researchers can create engaging and effective learning environments that cater to students' diverse needs and learning styles. To support novice programming students in Africa better, global solutions such as AR, chatbots, and educational games can be adapted to the continent's unique challenges. AR tools, optimised for low-cost mobile devices, can provide immersive, interactive experiences that are accessible, even in regions with limited infrastructure. AI-powered chatbots, such as PythonBot, can offer real-time personalised feedback in local languages, making programming education more accessible. Educational games can be tailored to local contexts using culturally relevant themes to engage students. Additionally, self-study tools and frameworks should be designed to accommodate varying levels of internet access, enabling offline learning for students in remote areas.

While the study underlines the global nature of contributions, it sheds light on the need for more extensive participation from various regions, particularly Africa. The comprehensive overview provided by this analysis not only informs the current understanding but also sets the stage for future research and collaborative initiatives in the realm of supporting novice programming students on a global scale. Furthermore, the global distribution of research efforts highlights the collaborative and cross-cultural nature of addressing educational challenges in programming. Collaborative initiatives involving researchers from different countries facilitate knowledge exchange and cross-pollination of ideas, ultimately enriching the research landscape and fostering global advancements in programming education.

6. Conclusion

The analysis of 37 articles focusing on novice programming students provides a comprehensive overview of the global landscape, highlighting significant contributions from the United States and Japan, with emerging support from Africa, primarily South Africa and Mauritius. However, a notable gap remains in participation from other African countries, indicating room for increased engagement across the continent. The solutions offered in the literature showcase a diverse array of approaches, including cutting-edge technologies, such as augmented reality and chatbots, instructional frameworks, educational games, and specialised tools for progress evaluation. These innovations aim to enhance accessibility and offer varied learning options to beginner programmers. Notably, advancements in chatbot technology, exemplified by IPO Chatbots and PythonBot, underscore the potential of AI-driven conversational agents to simplify programming learning and analysis. To help inexperienced programming students in Africa, it is necessary to customise global solutions, such as AR, chatbots, and educational games, to specifically address the distinct requirements of the continent. For instance, AR technologies might be adjusted to be compatible with inexpensive mobile devices, enabling engaging

experiences, even in regions with insufficient infrastructure. The study highlights the need for increased engagement from other regions, especially Africa, despite the global character of contributions, to create a more inclusive and balanced research landscape. The findings of this study are limited to publications in the selected databases. Research including a wider selection of databases could expand the geographical scope of research to include more diverse regions within Africa, Europe, and Oceania, and provide a more comprehensive understanding of global contributions to supporting novice programming students. Future work could involve collaboration with local educational institutions and organisations to promote research initiatives and facilitate knowledge exchange. Additionally, incorporating qualitative research methods such as interviews or surveys with educators and students could offer valuable insights into their experiences and perspectives regarding the effectiveness of different educational interventions.

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