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Exploring the Applications and Impacts of Voice Assistants: A Comprehensive Review Focused on Education and Academic Services

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Abstract: This systematic review aims to evaluate the applications and impacts of voice assistants (VAs) in supporting academic services. Searches explored the use of VAs in educational environments and for providing academic services in scientific databases (articles published from 2018 to 2023). The analysis of 25 articles reveals a predominance of exploratory applications and a scarcity of VA integrations with current academic systems. Concerns about data privacy and security were recurring themes, while the positive pedagogical impacts of audiovisual applications in academic services still lack solid evidence.

Keywords: Voice Assistants, Academic Services, Voice Assistants in Education, Integration in Universities

Explorando as Aplicações e Impactos dos Assistentes de Voz: Uma Revisão Abrangente Focada em Educação e Serviços Acadêmicos

Resumo: Esta revisão sistemática tem como objetivo avaliar as aplicações e impactos dos assistentes de voz (VAs) no suporte a serviços acadêmicos. As pesquisas exploraram o uso de VAs em ambientes educacionais e na prestação de serviços acadêmicos em bases de dados científicas (artigos publicados de 2018 a 2023). A análise de 25 artigos revela uma predominância de aplicações exploratórias e uma escassez de integrações de VA com os sistemas acadêmicos atuais. Preocupações com privacidade e segurança de dados foram temas recorrentes, enquanto os impactos pedagógicos positivos de aplicações audiovisuais em serviços acadêmicos ainda carecem de evidências sólidas.

Palavras-chave: Assistentes de Voz, Serviços Acadêmicos, Assistentes de Voz na Educação, Integração nas Universidades

1. Introduction

Although technology applies to various sectors of society, its practical application in enhancing learning remains a relatively unexplored topic (Schindler *et al.*, 2017). With the rise of virtual classrooms, voice assistants (VAs) have become vital as they facilitate interaction on devices such as smartphones, tablets, and computers, assisting in academic research and access to university services (Pereira *et al.*, 2022; Villegas-Ch *et al.*, 2021). Virtual assistants rely mostly on VAs, as they are interactive software that uses natural language, being more efficient when implemented with voice (Singh *et al.*, 2018). These assistants have various synonymous terms, such as machine conversation system, voice assistant, and chatbot (Ghose and Barua, 2013; Madhu *et al.*, 2017).

VAs are essential for modernizing Education beyond student support and facilitating complex administrative processes. For people with disabilities, VAs are transformative, with the potential to promote academic inclusion. The development of VAs in Education must prioritize accessibility to benefit all students, regardless of their abilities.

Given the increasing relevance of VAs, especially when combined with voice resources that also assist people with disabilities, we conducted a Systematic Literature

Review (SLR) focusing on the implications of this resource in Education and academic services. The insights obtained here may guide future research and developments.

2. Methodology

The research methodology for conducting the SLR followed the guidelines proposed by Biolchini and colleagues. (2005) and Kitchenham and colleagues (2009). The stages that define the adopted methodology consist of defining research questions (RQ) (Section 2.1), developing search strategy (Section 2.2), defining inclusion criteria (IC) and exclusion criteria (EC) (Section 2.3), selecting primary studies and data extraction (Section 2.4), and analyzing the quality of the studies (Section 2.5).

The management of the bibliographic references occurred by adopting *Mendeley* (https://www.mendeley.com), a citation and reference management platform. The elaboration of the SLR protocol occurred by using *Parsifal* (https://parsif.al), an online tool that helps structure and document the systematic review process. The article selection occurred by using *Rayyan* (https://rayyan.ai), an online platform for collaborative review.

2.1. Research Questions

Table 1. Present research questions used in this work.

ID	Research Questions
RQ1	What are the main applications of VAs in different contexts, including Education and academic services support?
RQ2	What are the main challenges in the application of VAs, especially in the Education sector and in the context of supporting academic services?
RQ3	What are the benefits of using VAs, particularly in Education and in supporting academic services?
RQ4	What are the evaluation criteria used to assess the effectiveness and efficiency of VAs in different contexts, including Education and supporting academic services?

2.2. Search Strategy

The search utilized the following databases: ACM Digital Library, IEEE, Science Direct, Scopus, and Springer Link. The search expression considered the feasibility of using VAs in the educational context, according to the present research objectives. The search expression used in the research databases was: ("Voice Assistant" OR "Voice Interface" OR "Voice Activated Interfaces") AND ("Academic" OR "University" OR "Student") AND ("Services" OR "Support" OR "Resources").

2.3. Inclusion and Exclusion Criteria

Scientific studies published between 2018 and 2023 were selected to address approaches of VAs in the Education, development, and functioning of VAs or to address improvements, techniques, and tools for VAs. Duplicate studies outside the scope of the SLR, with fewer than five pages, without complete and unrestricted access, and not written in English, were excluded.

2.4. Selection of Primary Studies and Data Extraction

Primary studies were selected in four progressive phases, as described by Unterkalmsteiner and colleagues (2012). In Phase 1, a search was conducted in selected databases using a specific search string, resulting in 1696 studies. In Phase 2, the analysis of titles and abstracts, using keywords and aligning them with the objectives of the SLR, reduced this number to 135 studies. In Phase 3, after applying inclusion and exclusion criteria and reviewing the introductions of the articles, 130 studies were

selected. In Phase 4, relevance and rigor criteria were applied, requiring a minimum relevance score of 4 and a rigor score of 2 or more, as described in section 2.5, resulting in 41 studies. In phase 5, the last stage of the process, 25 studies were selected for data extraction, considering only those whose application areas are Education or Human-Computer Interaction (HCI), among the 41 studies initially analyzed. This criterion was adopted because, although HCI is not directly related to Academic Services, this area encompasses fundamental research with the potential to enrich the field of Education. The details will be presented in the next section. Table 2 summarizes the stages of the study selection process throughout the five phases.

Table 2. Phases and number of selected studies.

Database	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
ACM Digital Library	644	63	62	23	17
IEEE Xplore	50	12	11	2	2
Science Direct	577	35	34	11	3
Scopus	26	6	4	2	1
Springer Link	399	19	19	3	2
Total	**1696**	**135**	**130**	**41**	**25**

2.5. Quality Criteria

A thorough evaluation of study quality and identification of convergence with the SLR objectives were adopted, following relevance (RE) and rigor (RI) analysis, adapted from (Martins & Gorschek, 2016). To evaluate the relevance of studies, we assigned 1 point to those meeting all quality criteria and 0 points to those that did not. Each study could earn up to 4 points (Table 3).

Table 3. Relevance of studies adapted from (Martins & Gorschek, 2016).

ID	Relevance assessment questions	Yes	No
RE1	Is the application of the study clearly defined?	130 (100%)	0 (0%)
RE2	Does the study mention challenges in developing VAs?	130 (100%)	0 (0%)
RE3	Does the study cite the benefits achieved in the application of VAs?	121 (93,08%)	9 (6,92%)
RE4	Does the study cite criteria for evaluating the effectiveness and efficiency of VAs?	45 (34,62%)	85 (65,38%)

Each question received 1 point if the articles fully met the established rigor criteria and 0 points if they did not meet these rigor criteria. Every study could achieve up to 3 points. The results of the rigor analysis are in Table 4.

Table 4. Rigor of studies adapted from (Martins & Gorschek, 2016).

ID	Rigor assessment questions	Yes	No
RI1	Does the study answer all research questions?	44 (33,85%)	86 (66,15%)
RI2	Does the study propose an application of AV to support academic services?	10 (7,69%)	120 (92,31%)
RI3	The study cites criteria for evaluating the effectiveness and efficiency of the application of VAs. And are these used in the study?	42 (32,31%)	88 (67,69%)

After applying relevance and rigor criteria, the number of studies reduced to 41. Six of these focused on the Education area with relevance 4 and rigor 3. Additionally, with

relevance 4 and rigor 2, there are 18 studies on human-computer interaction and one on Education. These studies are distributed throughout the dataset, as shown in the distribution presented in Figure 1.

Considering only the studies in the field of Education and human-computer interaction, as justified in section 2.4, we reached a total of 25 studies, as highlighted and presented in Figure 1. This figure emphasizes the area of Education and human-computer interaction, and the most relevant studies for this work.

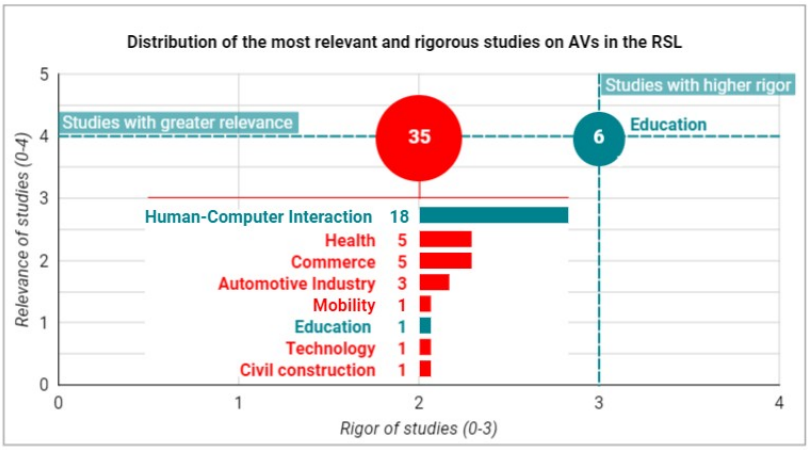

Figure 1. Distribution of 41 studies (35+6) on VAs. Those with higher relevance and rigor in Education and human-computer interaction sum out 25 studies (19+6).

3. Results and Discussion

This systematic review analyzed 130 studies published between 2018 and 2023 on applying VAs across various sectors, with the distribution of studies by year presented in Figure 2. These studies reveal challenges, benefits, and evaluation criteria for the effectiveness of VAs and discuss techniques for their specification, modelling, and development. There were more publications in 2022, accounting for 30.77% of the total studies, with considerable production in 2021 and 2023, at 24.62% and 18.46%, respectively.

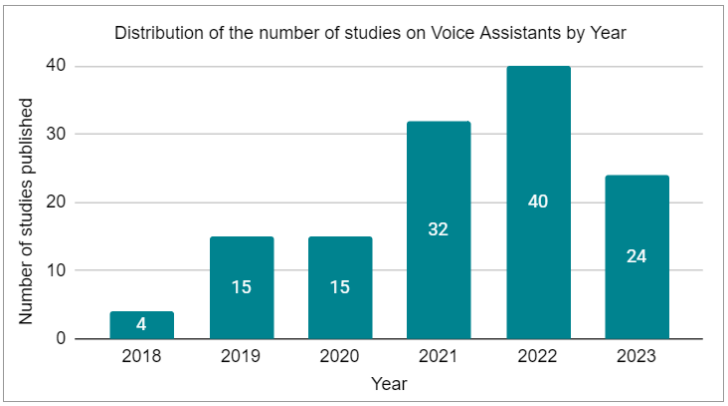

Figure 2. Distribution of the Number of Studies on Voice Assistants by Year.

The increase in academic production from 2019 onwards coincides with significant innovations in the field of AI, such as the ChatGPT language model at the end of 2020. This advancement revolutionized how people communicate and learn in the digital environment and sparked renewed interest and further research in VAs. As a result, in the subsequent years, especially in 2022, a substantial expansion in academic production was observed, emphasizing the considerable impact of these technological advancements.

Figure 3 illustrates that, out of the total selected articles (130), 43.08% applied VAs in Human-Computer Interaction. Usability was a key challenge, highlighted in 16.92% of the studies, while 18.46% reported improvements in User Experience due to VAs. Finally, the criteria used to evaluate the most relevant voice assistants are (Usability and User experience) and (Attitudes and perceptions), totaling 10% of the studies.

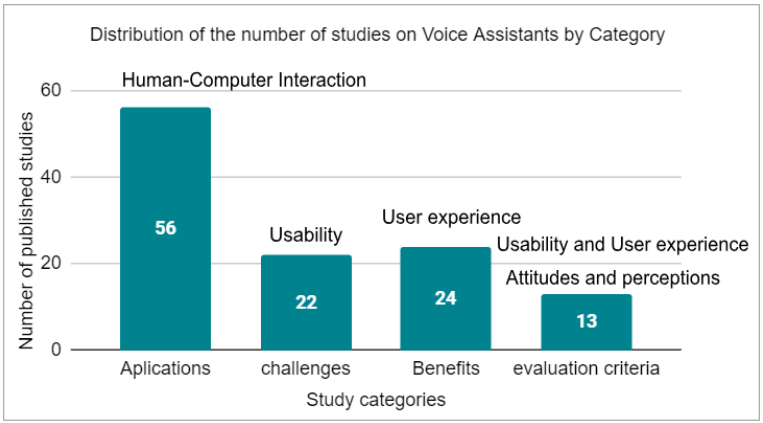

Figure 3. Number of studies published on VAs related to applications, challenges, benefits, and evaluation criteria from 2018 to 2023.

Regarding Academic Services, only 7.69% of the studies focused on this topic, indicating a vast area for further exploration of VAs in Education, an area still not widely investigated.

As for answering the Research Questions (RQ), criteria were applied, and studies with a relevance score of four and rigor greater than or equal to two were selected. By adhering to these rigorous criteria, the analysis ensures a robust examination of pertinent literature, aiming for comprehensive insights into the subject matter. This strategic approach, highlighted in Figure 1, underscores the meticulousness essential for reliable and insightful research outcomes.

3.1. Applications of VAs, Including Education and Academic Support Services (RQ1)

The most relevant applications were identified by applying the relevance and rigor criteria (Section 2.5). In studies with higher rigor (Rigor 3), Education represents 24% of the total, highlighting its importance. However, in Human-Computer Interaction, especially in studies with Rigor 2, the highest expressiveness is observed, representing 72% of the total. One additional study related to Education was identified as contributing 4% to the total.

The findings indicate that Human-Computer Interaction (HCI) studies tend to dominate, particularly those with Rigor 2, as Education remains significant, especially in studies with higher rigor. Those findings underscore the importance of Education in developing and evaluating voice assistant technologies. The presence of an additional study focused on Education further emphasizes the interest in incorporating voice assistants in educational settings. As a result, continuous research and development are still needed in Education and human-computer interaction to explore the potential of voice assistant applications.

3.2. Challenges in the Application of VAs in Education and Academic Support Services (RQ2)

With a Rigor score of 3, Precision (8%) emerges as the critical challenge for VAs, while Security, Education and Lifelong Learning, Communication, and Evaluation all

stand at 4%. Among the challenges with Rigor 2, Security and Communication (16%) prevail, highlighting the importance of ensuring user data protection and effectiveness in interaction between users and VA systems. Usability, with 12% and reliability, with 8%, indicate the need for intuitive interfaces and reliable systems for a positive user experience. Transparency, accuracy, personalization and empathy, integration with other systems, feedback and guidance, and ethics are all with 4% each. A more detailed analysis of the challenges are as follows:

Limited academic usage:

• VAs are still in the early stages of adoption in Educational settings, focusing on non-educational contexts, posing a challenge to their widespread application (Rohan *et al.*, 2023).

Language and accent sensitivity:

• VAs, being sensitive to various aspects of conversation, such as accent and speech speed, may pose challenges for regions that do not speak English, affecting user experience and adoption rates (Rohan *et al.*, 2023).

Need for skill development:

• Future research should focus on developing skills that increase student engagement and make learning enjoyable to facilitate mass adoption of VAs for educational purposes (Rohan *et al.*, 2023).

Exploration of real-time monitoring:

• The potential of VAs for real-time monitoring and intervention in Education remains underexplored, indicating the need for further investigation to leverage this capability effectively (Lee *et al.*, 2021).

3.3. Benefits of Using VAs in Education in the Context of Academic Support Services (RQ3)

In studies with Rigor 3, User Experience (8%) is the most notable benefit of AVs, followed by Personalization, Effectiveness, Communication, and Accessibility, all at 4%. In contrast, in studies with Rigor 2, User Experience (20%) is the main observed benefit, followed by security (12%), privacy and accuracy, both at 8%. There are also privacy and security, accuracy and security, user experience and personalization, Effectiveness and Efficiency, Effectiveness, Reliability, and Usability, all at 4%.

The benefits are grouped as follows for the sake of clarity:

Enhanced User Experience:

• VAs have the potential to enhance user experience by enabling hands-free and eyes-free interactions, leading to reduced cognitive load and distraction for users, particularly beneficial for those with visual impairments.

• Studies by Seymour (2023) and Braun and colleagues (2019) highlighted the positive impact of VAs on user experience, emphasizing the convenience and accessibility they offer through hands-free and eyes-free interaction features.

• The ability of VAs to provide a seamless and intuitive user interface contributes to a better user experience, allowing users to interact with the technology more naturally and efficiently.

Personalization and Educational Feedback:

• It was found that the AI virtual character Andy enhances social skills in children with autism spectrum disorder, potentially due to personalized feedback, as indicated by Hsu and colleagues. (2023).

• VAs can create personalized and interactive learning experiences in higher Education, providing personalized educational feedback to students, as mentioned in the study by Ong and colleagues (2019).

Support for Individualized Learning:

• VAs have been shown to offer individualized support by providing personalized feedback to help students overcome specific challenges, as demonstrated in the study by Kloos and colleagues. (2019).

• The ability of VAs to utilize users' personal information can further enhance individualized learning experiences, as suggested by Al Shamsi and colleagues (2022).

Efficiency in Academic Administration:

• VAs developed for platforms like Moodle can accelerate access to educational materials, increasing convenience and potentially streamlining administrative tasks in educational environments (Rohan *et al.*, 2023).

Accessibility and Inclusion:

• VAs offer greater efficiency than gesture-based interfaces, particularly beneficial for users with disabilities, showing their potential to promote accessibility and inclusion in Education (Rohan *et al.*, 2023).

Automation of Repetitive Tasks:

• VAs can automate access and retrieval of information, allowing educators to focus on higher-value activities, thus simplifying administrative processes in academic settings (Rohan et al., 2023; Melton & Fenwick, 2019).

Real-Time Monitoring and Intervention Potential:

• VAs promise real-time monitoring in Education, facilitating early detection of learning challenges and immediate interventions, although this area requires further exploration in research (Rohan *et al.*, 2023).

3.4. Criteria Used to Evaluate the Effectiveness and Efficiency of VAs in Different Contexts, Including Education and Academic Support (RQ4)

In studies with **Rigor 3**, Usability and user experience are predominant, totaling 16%, followed by Technical Performance and Attitudes and perceptions, with 4%. On the other hand, in studies with **Rigor 2**, Technical Performance stands out significantly, representing 24% of considerations, indicating a strong emphasis on user experience and perception regarding VAs. Usability, user experience, attitudes, and perceptions have prominence, with 16%. Social and Emotional Aspects represent 12%, while Validity and reliability correspond to 8%. Next, we examine important characteristics related to the evaluation criteria:

Trends and Patterns Analysis:

• In this aspect, several studies have shown a significant focus on "Usability and user experience" (32%) (Phinnemore *et al.*, 2023).

• Another significant aspect is "Technical performance" (28%), covering aspects such as accuracy, reliability, and functional capabilities (Zargham *et al.*, 2022).

• Studies also explored "Attitudes and perceptions" (20%) of users towards voice assistants, clarifying user satisfaction and ease of use (Baughan *et al.*, 2023).

• Limited attention has been given to the "Social and emotional aspects" (2.44%) of user interaction with voice assistants, indicating a potential area for future research (Zargham *et al.*, 2022).

Comparison among studies:

• Research conducted by Seymour (2023), Chen and colleagues (2021), and Braun and colleagues (2019) highlighted "Usability and user experience" with criteria such as "Task completion time" and "User satisfaction" (Zargham *et al.*, 2022; Zhang & Das, 2021).

• Despite variations in user groups (children, elderly, visually impaired), evaluation criteria remained consistent, allowing for exciting comparisons between these studies.

Identification of Literature Gaps:

• Voice assistant research has paid little attention to "Social and emotional aspects", with only 2.44% of studies addressing this theme (Al Shamsi *et al.*, 2022).

• There are opportunities to investigate the "Perception of warmth and naturalness of voice" (Al Shamsi *et al.*, 2022), as well as to further explore "Validity and reliability" (Al Shamsi *et al.*, 2022).

• Future studies can explore the predictability and consistency of assistant behavior, user understanding of the functionality, and perception of reliability (Al Shamsi *et al.*, 2022).

Direction for Future Research:

1. Multifactorial approach:

• Using multiple criteria in voice assistant evaluation suggests the advantage of a multifactorial approach (Lee *et al.*, 2021).

• Al Shamsi and colleagues (2022) employed nine measures, including acceptability, effectiveness, and comprehensibility, indicating a holistic evaluation approach.

2. Holistic evaluation:

• As Al Shamsi and colleagues (2022) proposed, future studies may consider incorporating a wide range of measures to assess voice assistants comprehensively.

Performance Benchmarks:

• Quantifiable metrics such as True Positive Rate (TPR), False Acceptance Rate (FAR), False Positive Rate (FPR) (Blue *et al.*, 2018), and Precision and Recall (Lee *et al.*, 2021) are essential for establishing performance benchmarks in voice assistants.

• These standards serve as valuable references for future VA development and guide desired performance levels (Lee *et al.*, 2021).

• Criteria cover user experience, technical performance, user attitudes, social and emotional aspects, and validity and reliability issues (Lee *et al.*, 2021).

• Specific criteria such as NASA-TLX workload and System Usability Scale (SUS) are being adopted, focusing on detailed aspects of human-voice interaction (Lee *et al.*, 2021).

4. Conclusion

This systematic review assessed the applications and impacts of voice assistants (VAs) in Education and academic services, analyzing 130 studies from 2018 to 2023. The results point to a predominance of exploratory applications of VAs, with gaps in integration with academic systems and limited evidence of positive pedagogical impacts. The review identified accuracy, security, skill development, and monitoring challenges. Key benefits include improvement in user experience, personalization, individualized learning, and accessibility. The evaluation of VAs encompasses criteria such as usability, technical performance, and socio-emotional aspects. While there is promising potential, more research focused on user-centered design, ethical implementations, and innovative pedagogical approaches is still needed to explore the transformative capabilities of VAs in Education fully.

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