

Voice Assistants and Artificial Intelligence in Education

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ABSTRACT

In recent years, Artificial Intelligence (AI) has shown significant progress and its potential is growing. An application area of AI is Natural Language Processing (NLP). Voice assistants incorporate AI using cloud computing and can communicate with the users in natural language. Voice assistants are easy to use and thus there are millions of devices that incorporates them in households nowadays. Most common devices with voice assistants are smart speakers and they have just started to be used in schools and universities. The purpose of this paper is to study the capabilities of voice assistants in the classroom and to present findings from previous studies.

CCS CONCEPTS

- Computing methodologies~Artificial intelligence

KEYWORDS

Voice assistants, artificial intelligence, smart speakers, education

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1 Introduction

In the last years, the heavy use of smartphones led to the appearance of voice assistants such as Apple's Siri, Google's Assistant, Microsoft's Cortana and Amazon's Alexa. Voice assistants use technologies like voice recognition, speech synthesis, and Natural Language Processing (NLP) to provide services to the users. A voice interface is essential for Internet of

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Things (IoT) devices that lack touch capabilities [1]. Besides smartphones, voice assistants are now incorporated in devices that are equipped with a microphone and a speaker to communicate with the users, called smart speakers (Fig. 1).

Most smart speakers come without a screen although there are smart speakers with screens such as the Amazon Echo Show and Echo Spot, the Facebook Portal, and the Google Home Hub (Fig. 2). The popularity of these devices is constantly rising since 2017. According to Canalys [2], smart speaker installed base will approach 225 million by 2020 and 320 million by 2022. Amazon Echo and Google Home devices are considered to reside in over 50% of US households by 2022 and global ad-spending on voice assistants will reach \$19 billion by the same year according to Juniper Research [3]. The Alexa platform is the dominant market leader, with more than 70% of all intelligent voice assistant-enabled devices (other than phones) running the Alexa platform [4].

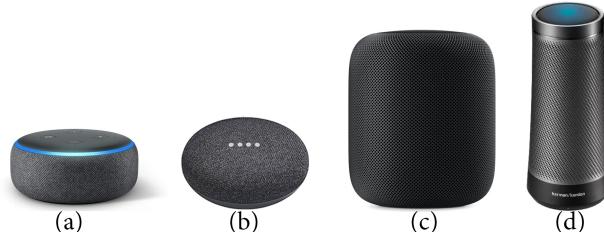


Figure 1: Smart speakers: (a) Amazon Echo Dot¹, (b) Google Home Mini², (c) Apple HomePod³ and (d) Harman/Kardon Invoke⁴

Voice assistants have several interesting capabilities. Most commonly used functions are [5]:

- answer to questions asked by users
- play music from streaming music services
- set timers or alarms
- play games
- make calls or send messages
- make purchases
- provide information about the weather

¹ <https://www.amazon.com/echodot>

² https://store.google.com/us/product/google_home_mini?hl=en-US

³ <https://www.apple.com/homepod/>

⁴ <https://www.harmankardon.com/invoke>

- control other smart devices (lights, locks, thermostats, vacuum cleaners, switches)

The capabilities of voice assistants are continuously extending. Amazon and Google have provided platforms for developers in order to extend their assistants' capabilities. Similar to mobile apps, Amazon Skills and Google Actions radically expand assistants' repertoire, allowing users to perform more actions with voice-activated control.



Figure 2: Smart speakers with screen: (a) Facebook Portal⁵, (b) Google Home Hub⁶, (c) Amazon Echo Spot⁷ and (d) Amazon Echo Show⁸

Some key elements that distinguish voice assistants from ordinary programs are [6]:

- NLP: the ability to understand and process human languages. It is important in order to fill the gap in communication between humans and computers
- the ability to use stored information and data and use it to draw new conclusions
- machine learning: the ability to adapt to new things by identifying patterns

Similarities and differences of devices and services regarding voice assistants have been studied in the literature in [7, 8]. In addition, as with any new revolutionary technology, scientific research and the educational community are considering whether these new devices can help the educational process. Something similar has happened before with personal computers and tablets [9, 10, 11]. This paper will present studies on the use of voice assistants and smart speakers in education. Our specific research questions (RQ) for the study are as follows:

- RQ 1: What interactions of adults and children with smart speakers have been reported in the literature?
- RQ 2: What are the beneficial use cases identified in the literature about using voice assistant and smart speaker technologies in education?

- RQ 3: What kind of security concerns do users have, regarding the use of voice assistants and smart speakers?
- RQ 4: What use cases have been identified in the literature regarding the use of voice assistants and smart speakers by people with disabilities?

The remainder of the paper is organized as follows. In Section 2 the methodology to retrieve related papers is described, while in Section 3 studies about smart speakers' home usage are presented. In Section 4, related work about AI, voice assistants and smart speakers in education is presented. Section 5 reports users' concerns about privacy and personal data regarding voice assistants and smart speakers. In Section 6, the usage of voice assistants and smart speakers by people with disabilities and the perspective of their use in special education is explored. Finally, Section 7 interprets the findings of this study while in Section 8, new areas for future research are recommended.

2 Methodology

In order to retrieve sufficient and high-quality papers regarding uses of voice assistants and smart speakers, the snowball technique as described in [12] was used. The technique has the following steps:

- Initially perform a search in Google Scholar, IEEE Xplore, Scopus and gather the initial start set of relevant papers. Keywords used were "voice assistant", "smart speaker", "amazon echo", "google assistant" and "Alexa".
- For the initial start set of papers, iterate through backward and forward snowballing. Backward snowballing uses the reference list to identify new papers to include, while forward snowballing refers to identifying new papers that cite the paper being examined. With backward and forward snowballing, new papers that are identified in each step, are put into a pile to go into the next iteration.

Using the snowball technique, 22 relevant papers were retrieved and all of them are referenced in this study. Research on this topic is very limited since the popularity of this new technology started to rise in 2017.

3 Home usage

There are few studies that explore the usage of smart speakers in homes and users' satisfaction. In [13] authors explored the degree of personification of the Amazon Echo devices, the sociability level of interactions and users' satisfaction, based on a total of 851 user reviews of the Amazon Echo posted on Amazon.com. Results indicate that there are variations in how people refer to the technology, with over half using the personified name "Alexa" and there is a moderate degree of sociability. Users report that they interact with the device for entertainment purposes such as listening to music, or for other functions like retrieving information, manage scheduling and shopping.

Interesting findings came also from [14] where authors explored how households incorporate conversational agents into

⁵ <https://portal.facebook.com/>

⁶ https://store.google.com/us/product/google_home_hub?hl=en-US

⁷ <https://www.amazon.com/echospot>

⁸ <https://www.amazon.com/echoshow>

their lives. Specifically, authors analyzed the logs of 75 Alexa users, for a total of 278,654 voice commands. Participants of the study also answered survey questions related to their household and use of Alexa and seven families who have owned an Alexa device for at least six months were interviewed. Of the 75 participants, 26 reported having children although data from the log files did not provide any insights into which household members gave each command. Parents that were interviewed, positively recalled their children successfully interacting with Alexa even before interacting with smartphones and other technology devices.

Children behavior is also investigated in [15] where 26 participants (3-10 years old) interacted with 4 voice assistants, Amazon Alexa, Google Home, Cozmo, and Julie Chatbot. Children were divided into groups of 4-5 and played with each voice assistant for 15 minutes. After each session with a voice assistant, children answered a questionnaire, in the form of a game, in order to analyze children's perception of the voice assistant. Authors also interviewed 5 children, to further probe their reasoning. Children enjoyed interaction with voice assistants, while older children perceived their intelligence and thought they could learn from them. The main issue of the interaction with children was getting the assistants to understand their questions although with the help of facilitators and parents, children altered their strategy and became fluent in voice interaction.

It is apparent that children are attracted and intrigued by the new technology. However, the role of digital assistants in child development at early ages should not be taken lightly. Parents should model healthy behaviors and usage and teach their kids that voice assistants are just tools [16] and not replacements of parents or teachers.

4 Education

In general, AI can be used in education in order to assist students in their learning process by providing fast and efficient information. For this purpose, Scarlet an Artificial Teaching Assistant is proposed in [17], although it is not tested in class yet. Scarlet is comprised by 3 modules: natural language processing, pseudo contextual data analysis and trial and error learning. In [18], an AI chatbot-based virtual assistant called LTKA-Bot is proposed. It is a virtual assistant to provide services regarding course activities such as record session data and services related to attendance, task assignment and scoring management.

In [19], ProblemPal, an Alexa Skill that enables teachers to automatically generate practice content with voice commands is proposed. The skill can create practice questions about any topic by using APIs from Wikipedia, Wolfram Alpha, and Khan Academy. Questions generated, are then uploaded and shared with students on Google Classroom. Although the skill was not tested in class, the study claims that it can reduce the workload of teachers and can also be a valuable tool for students.

A classroom setting is proposed in [20]. The author suggests that each classroom can contain enough microphones in order to recognize each student's voice and provide through voice

assistants, personalized answers to each student's headphones. Alternatively, each classroom can have a question station where each student can go and ask a question to a smart speaker. Teachers should get real-time data from voice assistant so that they can intervene when they see fit. The devices used in the setting are not seen as replacements for teachers, rather than amplifiers for their work.

Results of the University of Idaho (UI) Echo Project that took place during the 2017-2018 academic year, are discussed in [21]. The initiative of the project was to investigate perceptions and challenges related to integrating AI in classrooms. The project impacted four school districts and 900 students with 90 Amazon Echo Dot devices. The Echo Dot device was selected due to its low cost and compatibility issues. Different types of people used the device, such as a music teacher, a math teacher, a school counselor, the administrator, the elementary teacher and the classroom assistant. Teachers were depending on Alexa for simplifying some classroom processes, especially with the use of timers and reminders. Students preferred to ask the voice assistant for information, rather looking up information on a computer or a tablet. Both parties were excited to use the device in the classroom and tried to find ways to use it in particular projects and situations and many of them were already using a similar device at home. The study also suggests the cooperation of teachers, professional programmers and computer science faculty, to create custom skills that were not found in the existing Alexa Skills catalog. The study did not include observational data or log files from the devices, but relied on self-report perception surveys and interviews.

The differences in student engagement when a teacher implements purposeful instruction on using the intelligent voice assistant Siri in upper elementary and middle school science classrooms is explored in [22]. Student engagement is associated with student graduation rates. High student engagement leads to increased teacher's satisfaction and enjoyment. Findings of the study shows that the relationship between technology and learning is too complex to make broad assumptions and there is no clear association between integration of Siri in 5th grade/middle school science classrooms and increase in student engagement. In [23], authors created a quiz custom Alexa Skill about Scotland and used it with students ahead of an excursion. Students used the Amazon Echo device and found the skill to be entertaining.

Since voice assistants are very good at math and in spelling words correctly, they can be used by primary school students for grammatical control and for verifying their results in math. In a study with elementary students in first and second grade [24], it was observed that students consistently confirmed their mathematical results and did not ask for help from their teacher.

5 Users' main concerns

Security and privacy concerns of voice assistants and smart speakers are expressed in [25, 26, 27], since devices must be listening at all times so that they can respond to users. Authors in [28], interviewed 17 smart speaker users and 17 non-users to find out their arguments for and against adopting this new technology and their privacy perceptions and concerns. Many

non-users believe that these devices are not useful at all and companies are not to be trusted. On the other hand, smart speaker users have fewer privacy concerns and rely on companies to safeguard their personal data which think are not interesting to others. They also place the devices in the house based on accessibility and sound. Some parents reported that their children enjoyed using voice assistants. Most of them purchased the devices in order to be early adopters of the technology and among the first to use it. As a proposal, authors suggest different accounts for children and the ability to mute the devices with audio commands. They also suggest that an incognito mode similar to web browsers should be present in order to prevent data collection from the companies. To address privacy concerns for recording devices, researchers in [29] propose recording indicators while recording.

Users' perception of privacy and the use of privacy controls is studied in [30]. Users reported that although they are aware of the ability to erase the audio logs of Google and Amazon devices or use the physical mute button, they did not use these functions. Users also reported that in some cases they use private browsing mode when surfing through the internet and they would like this to also be available in the case of smart speakers.

Privacy is also considered in [27] since anyone with access to a voice-activated device can ask it questions, gather information about the accounts and services associated with the device, and ask it to perform tasks. As stated in [20], since devices can distinct children's voices, their specific learning needs are certain to raise questions with the Children's Online Privacy Protection Act (COPPA) and the Family Educational Rights and Privacy Act (FERPA).

6 People with disabilities

For many users, the ability to read and type is a difficult task for accessing information and it is believed that voice assistants can help with these tasks. Authors in [31], study speech-based conversational interfaces for the cognitively impaired, i.e. people with neurological disorders with minor impairment in instrumental activities of daily living including reading and writing difficulties. They also note that applications of conversational interfaces and voice assistants for people with cognitive impairments is scarce. The participants of the study emphasized the interest and motivation to use novel technical solutions such as voice assistants and have high expectations regarding conversational user interfaces. They believe that voice assistants should not be passive but to initiate a conversation with the users in certain conditions. They also point out that voice assistants should be a complement and not a replacement to personal contact with other humans. Authors conclude that voice assistants can act as a conversational partner and help to diminish the feeling of loneliness.

In special education, the use of AI is studied in [32]. The study examined the education efficacy of a learning environment called ECHOES and included 29 children with Autism Spectrum Conditions (ASC) aged 4-14 years old. ECHOES includes a virtual AI character called Andy which serves as a social partner

for children with ASC. Children interacted with ANDY and a human practitioner, blending human and AI interaction. Results showed a significant increase in the proportion of children's responses to the human social partners and suggested positive trends with respect to children's initiations to both social partners.

The popularity of smart speakers among people with disabilities is significant. By analyzing the reviews of verified purchases of Amazon Echo devices in [33], authors found out that almost 38% of reviews mentioned disabilities related to individuals with visual impairments or blindness, suggesting that voice assistants can be of great use by this community. Findings from [34] also confirm that voice interaction is convenient for blind people and help them make possible day-to-day tasks which other people may take for granted.

7 Discussion

In the previous sections, research about the usage of voice assistants and smart speakers in homes and in schools was presented. Reports regarding security, personal data and usage from people with disabilities were also included.

Regarding RQ1, early findings from a small number of studies, show that adults [13, 15] and children [14, 15] can interact with smart speakers and voice assistants, making basic requests, successfully and without much trouble. Basic requests include asking for information, weather forecasting, playing music, making purchases, or using them for conversation. Additionally, children were found to be attracted and intrigued by the new technology, although as noted in [16], it is vital for parents to teach their children that smart speakers and voice assistants are just tools and they should not rely heavily on technology during their daily routines.

Regarding RQ2, attempts on custom built AI assistants like Scarlet [17] and LTKA-Bot [18] and their usage in education are still in an early phase since Scarlet is not yet tested and LTKA-Bot is still under active development. The same applies for ProblemPal [19], an Alexa Skill that allows teachers to create practice content for their students for virtually any topic, since it is not tested yet. The author in [20] proposes a voice-activated classroom setting that will engage students, although the setting is not yet tested. It is believed that students from now on will be expecting individualized resources that smart speakers and voice assistants can provide, and not a passive environment. A significant large-scale study [21], regarding 900 elementary students with 90 Amazon Echo Dot devices concluded that the usage of voice assistants and smart speakers in the classroom can be beneficial and exciting in most cases for both teachers and students. It must be noted that detailed data regarding students' age were not presented and findings relied on self-report rather on observation. Furthermore, inconclusive findings come from [22] where authors claim that there is no clear association between integration of a voice assistant in 5th grade/middle school science classrooms and increase in student engagement. At the university level in [23], a custom skill for Alexa Echo devices was created and all students found the device and the

skill to be entertaining, although the study does not provide any input on sample size or any other result. Inconclusive input also applies in [24] where echo devices were introduced to elementary students in first and second grade. There is not any detailed information regarding the sample size and the way data was collected. In conclusion, regarding RQ2 and the use of voice assistant and smart speaker technologies in education, limited studies showed encouraging results even from early stages of education, i.e. kids at first and second grade of elementary school, although it is evident that more research on the topic is needed.

Regarding RQ3, 6 related studies [25, 26, 27, 28, 29, 30] suggest that security and privacy concerns are major drawbacks for users of voice assistants and smart speakers. Studies [28, 30] suggest that devices must be able to turn off by using voice commands instead of the physical mute button and that there should be an incognito mode where users can use the devices without being monitored. In some studies [25, 29], authors propose that devices should have obvious visual indicators regarding collection and transmission of data. Moreover, authors in [26] studied the security vulnerabilities of Amazon Echo Dot devices and discovered that acoustic attacks can be performed while victims are not at home. As a result, in case of using the technology in schools, it is crucial that these concerns must be addressed.

Regarding RQ4, 4 related studies [31, 32, 33, 34] show that there can be uses for voice assistants and smart speakers in special education, since many people with disabilities already use this promising technology in every day basis [31, 33]. Furthermore, for the cognitively impaired, i.e. people with neurological disorders with minor impairment in instrumental activities of daily living including reading and writing difficulties, authors in [31] conclude that voice assistants not only can assist in their daily routine, but they can also act as a conversational partner. Additionally, the potential to facilitate autistic children's ability to engage in social interaction by using AI agents is demonstrated in [32]. Furthermore, for people with a broad range of disabilities, even some with hearing loss and speech impairments, authors in [33] found that by using voice assistants, they complete more independently everyday tasks. Finally, for blind people, authors in [34] conclude that voice interaction is convenient for them and can play an important role in evoking feelings of independence and empowerment among them.

Conclusively, limited research on the use of voice assistants and smart speakers, suggest that this new technology can attract children from an early age. and can also assist people with disabilities. The question however is whether these devices can be used in education. The same issue arose when computers became popular.

It is interesting that data from Organization for Economic Cooperation and Development (OECD) show that although the usage of Information and Communication Technology (ICT) in schools is rising, literacy levels and mathematical skills of students who have computers and other ICT equipment in their classrooms dropped [35]. This issue is also addressed in [36] and the main reason that technology has not been as much helpful as

expected to the education system comes from the lack of proper training for both students and teachers.

Thus, the use of technology by itself is not enough. Proper training for teachers is needed in order to adopt and use smart speakers in the classroom. Additionally, as stated in [37], AI can be helpful for learners providing personalized learning since different students respond differently to distinct motivations. Smart speakers should provide answers based on who is asking them and they can also include the name of who is asking in their response.

Since there are many concerns regarding privacy and security, smart speaker companies should address them in order for the devices to be used in the classroom. Studies show that smart speakers can be used as a source of knowledge in classrooms as they are now used in homes. Children can direct their questions to the devices and verify their results, instead of asking the teacher. Students are pushed to perform their questions in a right and comprehensible way by the devices, understanding the basic principles of human-computer interaction. Besides information, voice assistants and smart speakers can activate students and push them to search for knowledge.

8 Conclusions

In this paper, research regarding the integration of AI voice assistants in education is presented. Research on this topic is limited since voice assistants and smart speakers are now gaining popularity. Findings presented in this paper will hopefully inspire other researchers to further investigate this topic. Smart speakers and voice assistants will be at the center of interest in coming years as they enter the everyday life of households. The ways they can be used efficiently in the learning process is the subject of research as there are many challenges. One of these challenges is the lack of many languages as voice assistants do not speak all languages. In addition, voice assistants do not have many of the appropriate security measures and protection filters that can be used in class by students. Teachers need to be trained and motivated about the usefulness of these devices in order to adopt them in their class. Although in most cases positive results have been reported regarding students and teachers, results are limited, incomplete and unorganized. As a conclusion, the role of these devices and their use in the classroom are still at an early stage of research and more studies need to address this topic.

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