**How Can Virtual Assistants and AI-Based Smartphone Apps Help Post-Secondary Students with Disabilities Succeed in their Studies?**

This scoping review (Sucharew & Macaluo, 2019) of the literature on the use of Artificial Intelligence (AI) tools and applications for learning by students with disabilities in postsecondary (higher education) institutions is intended to reflect the current state of empirical research, both quantitative and qualitative, and to inform educational practitioners and interested scholars of expectations for and actual employment for learning of those types of technology that may be encompassed under the AI umbrella.

Our preliminary consultations with an international team of researchers indicated that the literature on the issue, though of apparent interest and timeliness, is rather sparse and predominantly descriptive, and that there is little consensus among stakeholders of how to define AI and AI-enabled functionality to facilitate learning. Subsequently, our systematic search strategy was built around the explicit use of the key-term “artificial intelligence”, supplemented by indications of relevant educational purposes, settings, and environments and of categories of learners.

**Search Strategy**

A targeted search strategy was developed to collect empirical scholarly literature focused on the intersection of artificial intelligence and digital tools intended to assist the learning of post-secondary students with disabilities. The primary method used were searches of bibliographic databases spanning multiple disciplines. In total, 10 databases were searched – education databases ERIC and Education Source, computer science database Computers & Applied Sciences Complete, engineering databases Inspec and ACM Digital Library, medical databases Medline and PsycINFO, and several multi-disciplinary databases: ProQuest Central, Academic Search Complete and Web of Science. To focus on more modern technologies, searches were limited to 2010 onward. Searches were also limited to studies published in English.

Although the searches were customized to take advantage of database-specific options and filters, the following is a typical representation of the strategy employed:

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| ("artificial intelligence" OR "machine learning" OR "intelligent tutor" OR "smart tutor" OR "virtual assistant")AND(disabilit\* OR disabled OR impair\* OR "special need\*" OR blind\* OR deaf\* OR handicap\*)AND("higher education" OR "post-secondary" OR "post-compulsory" OR college OR university OR undergraduate)AND(teach\* OR learn\* OR educat\* OR instruct\* OR classroom OR school\*) |

To complement the formal literature searches, a parallel strategy was employed to locate grey literature using the Google search engine, as well as Google Scholar. A series of targeted searches were run, with the first several pages of results scanned for relevant materials. Furthermore, a variety of materials collected by the first author (Fichten) over the past year, consisting of blog posts, press releases, conference papers, etc., were also added to the collection.

Initial search trials on two databases were run at the end of July 2020 and then updated along with the remaining searches during the final week of 2020. All located materials were imported into the bibliographic management software Endnote for processing, with duplicates removed. Finally, after several literature reviews were identified in the results, the bibliographies of these reviews were scanned for additional relevant articles (recorded below under ‘branching’).

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| --- | --- | --- |
| **Data Source** | **Initial Results** | **Results after duplicates** |
| ERIC | 20 | 20 |
| ERIC update | 6 | 1 |
| Education Source | 12 | 10 |
| Education Source update | 0 | 0 |
| ProQuest Central | 67 | 66 |
| ProQuest Central update | 4 | 1 |
| Web of Science | 10 | 6 |
| Web of Science update | 12 | 3 |
| Google Scholar | 22 | 18 |
| Google Scholar update | 5 | 1 |
| PsycINFO | 15 | 12 |
| PubMed | 43 | 31 |
| Academic Search Complete | 30 | 19 |
| ACM Digital Library | 27 | 27 |
| Computers & Applied Sciences Complete | 6 | 1 |
| Inspec | 27 | 26 |
| Grey literature collection | 54 | 54 |
| Branching | 9 | 9 |
|  |  |  |
| **TOTAL** | **369** | **305** |

**Inclusion Criteria and Screening Results**

For the purposes of a scoping review, clear cut inclusion/exclusion criteria, more typical for quantitative syntheses (i.e., meta-analyses), for example, sufficiency of statistical data or type of the research design (with only ‘true experiments’ and ‘high-quality quasi-experiments’ to be admitted) are less likely to be easily identified and applied. Instead, the review was guided by more loosely formulated criteria, such as:

(1) A document under review contains some reference to a broad class of technologies, which explicitly described as having AI qualities that (2) necessarily are used by postsecondary students with physical (but not intellectual) disabilities to (3) provide them with various means of learning assistance.

We were open to either qualitative or quantitative empirical studies, as well as to descriptive studies (for example an article describing the development of specific tool without any experimental testing).

Subsequently, the 305 information sources found were next screened for relevance by title and abstract (using the above inclusion/exclusion criteria), with the sources judged to be one of the following:

1) Irrelevant (262)

2) potentially relevant, empirical (25)

3) potentially relevant, non-empirical (21)

 There were many reasons for irrelevance – some studies focused on the incorrect population group (not post-secondary students and/or not disabled), and many were studies that used artificial intelligence in the diagnosis of various special needs or disabilities. The full text of the 46 potentially relevant studies were retrieved and screened for relevance. After this screening, 4 empirical studies and 9 non-empirical publications were retained for final review and analysis.

**Research Questions**

As stated earlier, the main objective of this scoping review is to explore the state of the research literature on the issue of the use of AI tools and applications to facilitate learning for postsecondary students with disabilities. Specifically, further review of the identified for potential inclusion full-text documents proceeded, closely guided by the following research questions.

1. *How does the research literature define AI-based learning assistance tools and applications?*
2. *What research methodologies are featured in the literature on AI-based learning assistance for students with disabilities?*
3. *What particular tools and applications are explicitly named in the educational research literature as falling under the category of AI learning tools?*
4. *What categories of students with disabilities are reported in the literature to use AI-based tools for their learning?*
5. *How does the research literature present the outcomes (both expected and observed) of AI use by students with disabilities – i.e., what outcome categories could be consistently identified and documented?*
6. *What themes / messages with regard to AI-assisted learning does gray literature (i.e., opinion and description articles) contain?*

**Overview of Results**

*1. How does the research literature define AI-based learning assistance tools and applications?*

 Few of the articles offered definitions of artificial intelligence; some used other similar terms to describe the concept: adaptive personalized systems, automated decision-making, model-based decision making, sensing systems, plan recognition, Bayesian networks, and machine learning (the most frequently occurring alternative). Two of the sources reported specific definitions the authors employed:

"Artificial intelligence, or AI, is a broad term that encompasses the act of investigating and creating technological systems that can imitate aspects of human intelligence, specifically learning and comprehension (Niveditha & Basavaraj, 2017, p. 12)."

“…the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings” (Encyclopaedia Britanica 2018). In this context, the focus is on machines which mimic the cognitive functions we associate with humans such as learning and problem solving (Russell and Norvig 2016) as well as speech recognition and production” (Wood, 2019, p. 139).

*2. What research methodologies are featured in the literature on AI-based learning assistance for students with disabilities?*

None of the identified studies used a rigorous experimental design. Two studies (Athanaselis et al., 2014; Rodolitz et al., 2019) reported a post-test only experiment. There was one detailed case study (Roach, 2018) and one qualitative study that reported the results of interviews and journal entries (Forbes, 2019).

*3. What particular tools and applications are explicitly named in the educational research literature as falling under the category of AI learning tools?*

The technologies used in the reviewed studies were categorized by common themes, with virtual assistants being the most common (but even then, in only 4 of the 13 reports).

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| **Category of technology** | **# in final set** |
| Adaptive Reading Assistance | 1 |
| Augmentative and Alternate Communication (AAC) | 1 |
| Automatic Speech Recognition | 1 |
| Sensory Augmentation | 2 |
| Smart Glasses | 1 |
| Smartphone Apps | 1 |
| Speech to Text | 1 |
| Text Summarization | 1 |
| Text to Speech | 2 |
| Virtual Assistants | 4 |
| Virtual/Adaptive learning environments | 2 |

 Various specific applications and technologies were mentioned in the gathered literature, but again there was very little emphasis on any one tool. The most prevalent were virtual assistant applications – Alexa (3), Amazon Echo (1), Siri (1), Google Assistant (1), with the focus being on facilitating the ability of disabled populations to speak to them and pass instructions.

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| **Specific branded technology** | **# in final set** |
| Agent-DYSL | 1 |
| Alexa | 3 |
| ALSHI (Adaptative Learning System for Hearing Impaired) | 1 |
| Amazon Echo | 1 |
| Apple Watch | 1 |
| Be Focused (app) | 1 |
| Breathe2Relax (app) | 1 |
| Circle of 6 (app) | 1 |
| CoLLeGE (Computer-based Laboratory for Language Games in Education) | 1 |
| EquatIO | 1 |
| gMath | 1 |
| Google Assistant | 1 |
| Google Glass | 1 |
| Habitica (app) | 1 |
| Left for Spending (app) | 1 |
| MoodPanda (app) | 1 |
| myHomework (app) | 1 |
| Oculus Rift | 1 |
| Pearson Accessible Equation Editor | 1 |
| Penultimate (app) | 1 |
| Raspberry Pi | 1 |
| Shopping List Ease (app) | 1 |
| Siri | 2 |
| Sit With Us (app) | 1 |
| Tacotron 2 (Google) | 1 |
| Tesseract (open source Optical Character Recognition Tool) | 1 |
| Verbal Victor | 1 |
| WaveNet (Google) | 1 |

*4. What categories of students with disabilities are reported in the literature to use AI-based tools for their learning?*

 There were various disabilities addressed by AI-based technologies within the literature, but sensory disabilities (sight, hearing) predominated.

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| **Disability** | **# in final set** |
| Autism Spectrum Disorder | 1 |
| Autoimmune diseases/Chronic Illness | 2 |
| Communication Disability | 1 |
| Dyslexia | 2 |
| Hearing Impairment | 4 |
| Visual Impairment | 6 |

*5. How does the research literature present the outcomes (both expected and observed) of AI use by students with disabilities – i.e., what outcome categories could be consistently identified and documented?*

 There was a greater emphasis on tool development, with some effectiveness trials, but student learning effects were not commonly addressed. For example, Rodolitz et al. (2018) report findings from an experiment with three conditions that are based on how inputs are given to a virtual assistant (Text to Speech, American Sign Language or Gesture) and how effective each is in getting Amazon Echo to understand the instruction. In Forbes (2019) we have a qualitative dissertation where users were asked about their use of virtual assistants in interviews - three specific aspects were of interest, including the features used, the user experiences, and how use minimized disability-related stress. In Athanaselis et al. (2014) there are some student outcomes – reading pace, accuracy, motivation, self-esteem, and relevance, that are tested after using a tool to help dyslexic students, with modest positive gains found.

*6. What themes / messages with regard to AI-assisted learning does gray literature (i.e., opinion and description articles) contain?*

 The grey literature frequently described the development of tools or applications (e.g. AlSaid et al., 2019; Amarawansha et al., 2019), while others reviewed tools and applications available to users with various disabilities (Francis et al., 2018; Wood, 2019) or explored the ethical issues that arise in their development (Findlater et al., 2019).

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