

RESEARCH REPORT

Use of an intelligent tutoring system for a curriculum on augmentative and alternative communication: Feasibility for implementation

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Abstract

Background: Over 8 million children with disabilities live in Africa and are candidates for augmentative and alternative communication (AAC), yet formal training for team members, such as speech–language therapists and special education teachers, is extremely limited. Only one university on the continent provides postgraduate degrees in AAC, and other institutions provide only short modules at an undergraduate level. The need for an introductory training course on AAC that is accessible by university students continent-wide was identified. An online programme, namely an intelligent tutoring system (ITS), was identified as a possible option to facilitate interactive learning without the need for synchronous teaching. The use of an ITS is shown to be effective in developing knowledge and clinical reasoning in the health and rehabilitation fields. However, it has not yet been applied to student teaching in the field of AAC.

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Aim: To determine both the feasibility of an ITS to implement an AAC curriculum for students in four African countries, and the usability and effectiveness of such a system as a mechanism for learning about AAC.

Method & Procedures: The study included two components: the development of a valid AAC curriculum; and using the ITS to test the effectiveness of implementation in a pre- and post-test design with 98 speech–language therapy and special education students from five universities.

Outcomes & Results: Statistically significant differences were obtained between pre- and post-test assessments. Students perceived the learning experience as practical, with rich content.

Conclusions & Implications: The findings suggest that the ITS-based AAC curriculum was positively perceived by the students and potentially offers an effective means of providing supplementary AAC training to students, although modifications to the system are still required.

KEYWORDS

augmentative and alternative communication (AAC), intelligent tutoring system (ITS), students, training

What this paper adds

What is already known on the subject

- Professionals typically lack formal training in AAC. In Africa, this presents a serious challenge as there are over 8 million children who are candidates for AAC. A need for an introductory training course on AAC, which can be accessed by university students continent-wide, was identified.

What this paper adds to existing knowledge

- An AAC curriculum was developed and integrated into an ITS, an online programme allowing interactive learning through asynchronous teaching. Students from four African countries completed the AAC ITS curriculum. The curriculum was positively received by the students and statistically significant changes in knowledge were identified.

What are the practical and clinical implications of this work?

- This feasibility study shows that the use of an ITS is an effective means of providing AAC training to university students in these African countries. The results provide a valuable contribution toward ensuring the equitable distribution of AAC training opportunities in the African context. This will have a significant positive impact on those who are candidates for AAC.

INTRODUCTION

Due to global knowledge dissemination and advocacy around augmentative and alternative communication (AAC) services, the positive effects of AAC have been recognized by individuals with complex communication

needs (CCN), their families and practitioners. This has resulted in a wider range of people inquiring about and receiving AAC services (Light et al., 2019). In particular, there is a growing, yet unmet, need for AAC services in resource-constrained contexts (Light et al., 2019) such as low- and middle-income countries (LMICs) in Africa and

South Asia where the large majority (approximately 95%) of individuals with disabilities live (Olusanya et al., 2018; Officer & Posarac, 2011). There is a paucity of disability and CCN incidence indicators in these countries. However, taking into account the global incidence of 1.3% of the world's population presenting with CCN (Beukelman & Light, 2020; Saleh, 2022), and considering population statistics with suggested higher incidence of disability in Africa, conservative estimates suggest that there could be over 8 million people with CCN who are candidates for AAC on the African continent alone.

AAC in LMICs

Specialized practices, such as AAC, that facilitate social inclusion are vital to limit the compounding influence of disability and context-related barriers in the lives of people who have a disability and reside in LMICs (Dada et al., 2017). While individuals with disabilities around the globe experience barriers to participation across many facets of their daily lives, these barriers are exacerbated for people with a disability and CCN who live in LMICs (Schlebusch et al., 2020). The lack of accessible and affordable healthcare and education, poorer infrastructure, and fewer opportunities for income generation disproportionately affect those living with disabilities in LMICs (Muttiah et al., 2022; Schlebusch et al., 2020). This results in their exclusion from many valued life activities such as community activities, social engagements, educational opportunities, and formal or informal income-generating activities (Dada et al., 2017; Schlebusch et al., 2020). They are also more likely to experience stigmatization and discrimination (Cramm et al., 2014).

In the African context, a shortage of speech-language therapists (SLTs) and special education teachers (SETs) and inadequate AAC training for members of both professions are a significant challenge to AAC service delivery (Adugna et al., 2022; Mukhopadhyay & Nwaogu, 2009; Wylie et al., 2018). Speech-language therapy, as a profession, is only just emerging in various African countries (Wylie et al., 2018). There are signs of the development of training programmes in several African countries, such as Ghana, Mozambique, Kenya and Uganda, with programmes under review in Zambia and Tanzania (African Connections Project, 2021; Wylie et al., 2018). In countries where the profession is more established (e.g., Egypt and South Africa), professionals still experience challenges with AAC service delivery, including a lack of training (Dada et al., 2017; Muttiah et al., 2015). A shortage of SETs has also been noted (Adugna et al., 2022). SETs who teach students with CCN also face several barriers to AAC implementation, such as inadequate training in AAC, lack of

knowledge and skills in AAC, lack of mentoring, and inadequate time for planning and preparation (Mukhopadhyay & Nwaogu, 2009; Tönsing & Dada, 2016).

Training in AAC

Although the implementation of AAC is influenced by a wide scope of individual and contextual factors (Costigan & Light, 2010), the knowledge and skill of the professional delivering AAC services have a bearing on the appropriateness of techniques and devices selected and the overall success of AAC implementation (Siu et al., 2010). The population of individuals who would benefit from AAC is heterogeneous, with each individual differing in skills, type of disability and life experiences (Sanders et al., 2021). Due to these factors, a collaborative team of professionals typically provides specialized AAC services. A lack of knowledge of AAC among professionals is a key barrier to effective, collaborative AAC service delivery (Uthoff et al., 2021).

Positively, various African countries have introduced undergraduate rehabilitation programmes in speech-language therapy (Wijesinghe, 2010). Undergraduate AAC training aims to equip students with basic competencies in AAC, such as recognizing the need for AAC and assessing for AAC intervention (Costigan & Light, 2010). Several US-based studies have shown that SLTs report dissatisfaction with the undergraduate training they have received in preparation for AAC service delivery. Suggestions have been made to improve undergraduate training in the application of AAC (De Bortoli et al., 2014; Sanders et al., 2021). Similarly, training in AAC is also recognized as a necessity by SETs as they have limited knowledge and skills in this area (Mukhopadhyay & Nwaogu, 2009). Furthermore, ongoing professional development and support of teachers and SLTs who implement AAC with children with CCN is required (Dada et al., 2023; De Bortoli et al., 2014). Training in AAC is imperative to support AAC service delivery effectively (Dada et al., 2023; Sanders et al., 2021). Given the probability of graduating professionals working with individuals who would benefit from AAC, graduating professionals need to have, at minimum, knowledge of the fundamental competencies in AAC as part of their skill set (Costigan & Light, 2010).

Africa has extremely limited formal AAC training options (Dada et al., 2023). The Centre for Augmentative and Alternative Communication is currently the only university on the continent which provides postgraduate training in AAC for professional stakeholders involved in AAC service delivery. Considering this challenge, the (Dada et al. 2017) has identified the need for a training course on AAC, which could be accessed by undergraduate students continent-wide.

Training using online platforms

With limited face-to-face formal AAC training options available across the African continent, an asynchronous, online training option that mitigates access challenges becomes particularly attractive. Online training proliferated as a result of the COVID-19 pandemic (Castro-Schez et al., 2021; Dhawan, 2020; Khoza-Shangase et al., 2021). Such options are recognized as efficient, cost-effective and easily accessible both economically and geographically (Costigan & Light, 2010; Dhawan, 2020; Khoza-Shangase et al., 2021).

Online training may be synchronous, where learner(s) and instructor(s) are all present at the same time. Instructors can provide support and real-time feedback (Schoenfeld-Tacher & Dorman, 2021; Suliman et al., 2022). In contrast, asynchronous online learning occurs at a different time and place for each learner. The instructor constructs a learning path for each learner to work through at their own pace and therefore real-time feedback may be absent (Schoenfeld-Tacher & Dorman, 2021; Suliman et al., 2022). Asynchronous online learning can allow for the revision of content as many times as needed, and engagement with step-by-step explanations and multiple examples across various media platforms, such as text, graphics and videos (Schoenfeld-Tacher & Dorman, 2021). This is particularly beneficial to students who are not first-language speakers of the language of instruction, or for whom the concepts being taught are novel. Such factors can improve engagement and promote higher order thinking (Mathew & Iloanya, 2016).

While online training has benefits, there are prerequisites for its implementation. For course developers and instructors, specific pedagogical skills are required to design and implement effective online learning (Mathew & Iloanya, 2016). In addition, in resource-constrained environments, access to technology may be limited by poor infrastructure and economic circumstances which create a digital divide. For example, concerns have been raised about the feasibility of online training in Africa due to bandwidth difficulties resulting in unreliable internet, limited internet availability, high internet costs, challenges accessing technology and technophobia (Krohn et al., 2021; Mathew & Iloanya, 2016). Asynchronous learning has been shown to be more accessible in this regard, as it can be developed to require lower bandwidth (Krohn et al., 2021). To provide AAC training to undergraduate students across Africa, an asynchronous online programme was identified as a training option.

Intelligent tutoring systems (ITSs)

An ITS provides a way to mitigate the disadvantage of lack of immediate instructor feedback in asynchronous online learning. ITS refers to educational software with an artificial intelligence component that can track students' work and adjust feedback, providing hints as they progress through a course (Shute & Zapata-Rivera, 2010). It can provide real-time feedback to students without the need for a staff member to be present. It allows for one-on-one tutoring, adapting to learners' needs by making suggestions, reiterating concepts, redirecting learners or allowing them to progress to the next section, to aid them in achieving learning outcomes (Castro-Schez et al., 2021; Magnisalis et al., 2011). A key element of an ITS is the function to include natural language processing. This allows the dialogue system of the ITS to keep track of the student's responses and make decisions about what the next system action should be, such as providing a further prompt when the student is close to finding the answer themselves. Natural language processing allows natural language information to be converted into a format that is machine-understandable so that answers provided by students can be processed by the ITS (Paladines & Ramírez, 2020). This allows students to reflect on their understanding in their own words without having to provide verbatim answers. Due to its allowance of greater cognitive engagement, immediate feedback and learner control, in some circumstances, the use of an ITS has led to greater achievement than traditional classroom instruction (Ma et al., 2014).

The use of an ITS has been effective in implementing training in the knowledge fields (e.g., general medical knowledge) and fields requiring clinical reasoning (e.g., differential diagnoses in head injury) (Sreenivasa Sarma & Ravidran, 2007; Suebnukarn & Haddawy, 2004). To the best of our knowledge, it has not yet been applied to training in the field of AAC. Training within AAC should develop knowledge and skills in AAC content areas as well as cultural competence, collaborative skills and problem-solving (Costigan & Light, 2010). These skills need to be applied to the specific needs of the population requiring AAC. Hence, AAC is an applied science which requires differential tutoring for each student. An ITS has been suggested as a possible tool for this purpose due to the ability of the system to differentiate the content that is provided based on the student's responses to questions (Castro-Schez et al., 2021; Magnisalis et al., 2011).

However, the efficacy of the ITS rests in the actual design of the system and the way that content is applied. The

use of case studies was identified to allow the students to link theory to practice by encouraging the application of knowledge to a clinical case (Thistlethwaite et al., 2012). This process has been identified as an effective strategy for the development of deeper learning of clinical skills, as it seeks to encourage the use of critical thinking, rather than the identification of the correct answer (McLean, 2016). In addition, a prompt-based tutoring guide was developed and integrated into the ITS for each module to provide specific prompts and guide the students towards the correct answer. By doing this, the ITS was not implemented to test specific knowledge, but rather to act as a tutor by guiding the student towards the expected answer when an incorrect answer is provided.

Considering the above factors, it was hypothesized that an online AAC programme delivered asynchronously through an ITS could be an effective and accessible way of training SLT and SET undergraduate or postgraduate students across Africa in AAC knowledge. The aim of this study was therefore threefold, namely (1) to develop an AAC curriculum appropriate for SLT and SET students in Africa; (2) to develop an ITS to implement the AAC curriculum; and (3) to test the developed programme with students from selected universities in Africa to evaluate its feasibility.

METHODS

Research design

A pre-/post-test design was used for this study. There were two main components to the research design. The first component involved the development of an appropriate AAC curriculum to be taught to university students in Africa. This curriculum was then integrated into an ITS. The second component involved the feasibility study of the ITS for teaching the developed curriculum. The effectiveness of the programme to increase knowledge of AAC was evaluated using a single-group pre- and post-test design. The usability of the ITS was evaluated using a rating scale, while the participants' perceptions of the ITS and the curriculum were also obtained using open-ended questions after the post-test.

Participants

Purposive sampling was used to identify six universities that offer an undergraduate or postgraduate degree in speech-language therapy or undergraduate training in special education teaching. The identified universities were sent an invitation letter via email. Of the invited

universities, five universities were provided with the necessary approvals from their academic institutions and agreed to participate. The other university did not provide timeous approval and permission for their students to be invited to participate in the study and were excluded.

Non-probability convenience sampling was used to select the undergraduate students who would test the feasibility of the ITS. The ITS AAC modules were put forward as preparatory modules for the academically credited module for which the students were already registered. The lecturers provided information about the module to their students. A total of 166 students were invited to participate. Of these, 134 students indicated interest in participating in the study by completing a Google Form linked to the invitation letter. Of these, 36 students did not provide consent to participate. A total of 98 participants from five universities consented to be involved in the study and completed the pre-test evaluation. Of these, 80 participants completed the AAC modules and post-test evaluation (18% dropout rate).

Demographics

Table 1 describes the participants who participated in the feasibility study, including; the universities in Africa where the students were enrolled, the languages the students spoke, the types of degrees in which they were enrolled, and the year for which they were enrolled. Most of the students (88.8%) indicated they had their own devices on which they would access the ITS. Students specified the type of technology they would be using, with 58.2% indicating they would be using a mobile phone and 40.8% a computer. More than half of the students (63.3%) did not have access to wi-fi and indicated that they would be using mobile data. Students indicated that 51% had limited data while 49% had access to unlimited data.

Materials

AAC modules

A team of professionals with specialist knowledge in AAC was purposively recruited to develop the AAC modules. The team comprised 21 individuals who were SLTs and SETs currently working in the field of AAC as clinicians, researchers, postgraduate students, or university lecturers. The researchers and academics were specifically recruited from (removed for review). Additionally, professionals were recruited from (removed for review).

For the development of the AAC curriculum, the professionals worked in groups to identify key concepts of AAC as the foundations of the curriculum to be taught within

TABLE 1 Demographics of participants.

Variable	Group	n	%
Gender	Female	77	78.6%
	Male	21	21.4%
Age group (years)	18–20	31	31.6%
	21–25	33	33.7%
	26–30	17	17.3%
	31–35	7	7.1%
	36–40	4	4.1%
	41–45	6	6.1%
University	University of Botswana, Botswana	40	40.8%
	Kenyatta University, Kenya	32	32.7%
	University of Ghana, Ghana	14	14.3%
	University of Fort Hare, South Africa	10	10.2%
	University of Kwa-Zulu Natal, South Africa	2	2.0%
Home language	Setswana (Botswana, Ghana, South Africa)	29	29.6%
	English (Botswana, South Africa)	27	27.6%
	Kiswahili (Kenya)	11	11.2%
	isiXhosa (South Africa)	10	10.2%
	Akan (Ghana)	6	6.1%
	Ewe (Ghana)	4	4.1%
	isiZulu (South Africa)	2	2.0%
	Ekegusii (Kenya)	1	1.0%
	Ga (Ghana)	1	1.0%
	Ikalanga (Botswana)	1	1.0%
	Kalanga (Botswana)	1	1.0%
	Kikuyu (Kenya)	1	1.0%
	Luo (Kenya)	1	1.0%
	Sesotho/Southern Sotho (South Africa)	1	1.0%
	Urdu	1	1.0%
	Waale (Ghana)	1	1.0%
Year of study	First	40	40.8%
	Second	20	20.4%
	Third	9	9.2%
	Fourth	29	29.6%
Enrolled degree	Special needs education	67	68.4%
	Speech–language therapy	27	27.6%
	Education	3	3.1%
	Bachelor of Education Science	1	1.0%

an African context. The key concept identification resulted in a curriculum which comprised four modules; (1) an overview of AAC, (2) assessment for participation, (3) communication partners in AAC and (4) literacy in AAC. Each module was developed by a group of professionals who were grouped according to their expertise. Module development included the identification and writing of content, case studies and questions relating to the key concepts. Lastly, a glossary of terms for each module was developed.

The glossary was developed in English and was then translated into seven additional languages of the participating countries including isiZulu, isiXhosa, Sepedi, Setswana, Akan, Swahili and isiNdebele.

The ITS

An ITS emulates a human tutor as the software can track students' work and adjust feedback given as they progress

through the modules, using artificial intelligence (Shute & Zapata-Rivera, 2010). The ITS used in this study was developed by (removed for review). Each AAC module was integrated into the ITS, through the inclusion of the content, case studies with application questions, and a tutoring guide for each module. The content for each module was provided to the participants in an accessible PDF format. Once downloaded, the content could be accessed without having to log into the ITS. This was done to address concerns regarding internet access and high internet costs (Mathew & Iloanya, 2016). For each module, a case study was presented in the ITS which related to the content of the module. The ITS would then present questions related to the case study to determine the participants' understanding and application of concepts within the module. The tutoring guide acted as a real-time tutor by guiding the participant towards the expected answer with probing questions if an incorrect answer was provided. Natural language processing was integrated within the ITS to ensure that participants could express themselves using their own words and understanding, rather than providing verbatim answers. Although students could download and save the module content, the case study, and the case study questions, the tutoring guide had to be accessed online, requiring an internet connection to work.

Pre-test questionnaire

Before receiving access to the ITS, participants had to complete a pre-test questionnaire. This was comprised of two sections: biographical information and AAC knowledge. The section on AAC knowledge included 21 close-ended questions comprising multiple-choice and true/false questions to determine the participants' AAC knowledge before completing the AAC modules. Questions 1 to 5 related to Module 1 (overview of AAC), Questions 6–10 related to Module 2 (assessment for participation), Questions 11–16 related to Module 3 (communication partners in AAC) and Questions 17–21 related to Module 4 (literacy in AAC). The questionnaire may be obtained from the corresponding author.

Post-test questionnaire

Once the participants had completed the ITS AAC modules (which took up to 4 weeks to complete), they answered the post-test questionnaire. This questionnaire consisted of repeated AAC knowledge questions and an additional section of questions about the usability of the ITS.

Due to the ITS being a novel training approach, an additional section of questions about the usability of the ITS was included but was not part of the pre-/post-test analysis.

It was necessary to gather information about each student's perceptions of the ITS. The ITS usability questions were adapted from the System Usability Scale (SUS), developed by John Brooke (Brooke, 1996; Lewis, 2018). The SUS is a widely used standardized questionnaire that assesses perceived usability. The SUS has been shown to be a flexible questionnaire, therefore minor word changes do not affect the scale (Lewis, 2018). The SUS was adapted to include questions related to the use of an ITS, using a positive version of the tool (i.e., only positively worded statements as opposed to a mix of statements with positive and negative tones), to get a retrospective measurement of perceived usability of the ITS (Lewis, 2018). Previous research has indicated that such adjustments maintain the reliability, validity and sensitivity of the tool (Lewis, 2018). Usability studies indicate that the SUS is highly reliable with a coefficient Cronbach alpha of 0.91, with guidelines indicating that values between the range of 0.7–0.95 are considered acceptable (AlGhannam et al., 2018). This usability section consisted of 16 items. Participants could indicate on a Likert scale (1–5) to what extent they agreed with each statement (where 1 = I don't agree/not at all and 5 = I agree/very much so). A higher rating, therefore, meant a more supportive perception of usability. Additionally, five open-ended questions were asked where participants could indicate what they liked most about the ITS AAC modules, what they liked least, what information was missing in the modules, challenges experienced, and suggestions for improvement.

Procedures

Ethical approval was granted by (removed for review), as well as at all participating universities. All participants provided informed consent to participate in the study.

Data collection

Once participants had provided consent to participate, the researcher provided them with a link to the pre-test questionnaire on a Google Form, the survey administration software used in the study to collect biographical information and AAC knowledge before the completion of the AAC modules. Once the pre-test assessment was completed, the participants were given access to the AAC modules and the ITS. Participants had 3 weeks to work through the modules. An extra week was provided for students requesting more time. After completion of the

modules, the participants completed the post-test assessment on Google Forms and then received a certificate of participation. All data were downloaded from Google Forms into Excel for data analysis. All participants who provided initial consent, whether they completed the study or not, were invited to attend a feedback session on Zoom to conclude this phase of the study. Only 12 students attended the Zoom feedback session. Preliminary results were shared with the participants and the participants were allowed to share their experiences with the ITS. The written feedback obtained in the Zoom chat as well as verbal feedback from the participants were transcribed.

A focus group discussion where students were asked nine questions to obtain feedback on their perceptions and experiences of the ITS-facilitated AAC curriculum modules. Three questions were close-ended questions and the rest were open-ended. Prompts were used to encourage the participants to reflect and provide further details on the questions.

Data analysis

Quantitative data from the study was analysed statistically. Changes in participants' AAC knowledge were determined by responses obtained from the AAC knowledge questions in the pre- and post-test questionnaires. Cohen's *d* was used to determine effect size (with $p > 0.2$ = small effect; > 0.5 = medium effect; > 0.8 = large effect). Descriptive statistics were used to analyse the usability of the ITS, based on the ratings of usability statements in the post-test questionnaire. Descriptive data were recorded in frequency tables to examine the usability ratings.

Qualitative data from the open-ended questions in the usability section of the post-test questionnaire on participants' perceptions of the ITS were analysed for patterns of themes. The Framework Method was used as it provides a highly systematic method of categorizing and organizing qualitative data to find patterns of similarity (Gale et al., 2013). In this study, we were interested in students' perceptions of the modules and specifically the ITS, and we particularly wanted to find out if there were common patterns in the way they experienced the learning engagement. Following the stages described by Gale et al. (2013), the second author read through all the participants' written responses for each question and the significance of each response was determined. Once the second author was familiar with the text, labels were assigned to emotions, ideas and impressionistic elements that were interpreted as important within the text. During the process, while coding the first few participant responses for each question, the second and third authors discussed the identified labels to develop a set of prelim-

inary areas of similarities in the perceptions of students, which formed a working analytical framework. This analytical framework was applied to the remaining responses so that all participant responses were indexed. The first author checked the classification of codes into themes. Disagreements were discussed until a consensus was reached (Dada et al., 2020; Gale et al., 2013). Member checking was conducted during the Zoom feedback session with participants at the end of the study and the general themes were confirmed.

RESULTS

Usability of the ITS and AAC modules

Quantitative ratings of usability were obtained using a rating scale included at the end of the post-test questionnaire. Table 2 provides descriptive information indicating the participants' usability ratings.

Participants were asked to indicate to what extent they agreed with each statement regarding the usability of the ITS. For all the questions, a mean of 4 was obtained with a standard deviation (SD) of 1.0 or less, indicating a positive perception of usability across all areas of the rating scale statements.

Participants were also asked to respond to open-ended questions regarding the usability of the ITS and their learning experience at the end of the post-test questionnaire. Three main themes were identified, which related to factors that facilitated their learning experience as they engaged with the AAC modules and the ITS. The identified themes included (1) ease of use of the ITS, (2) practical elements and (3) perceptions regarding the content of the modules. A barrier to implementation was identified relating to each facilitating factor. The first theme related to the ease of use of the ITS. Participants reported that the system was simple to use, with the content explained in a manner that was easy to understand. The arrangement of the modules and ITS was perceived as systematic, adding to the ease of use. Despite the mostly positive perceptions, one barrier related to the system itself was repeatedly noted. Participants explained that the system required constant refreshing due to freezing of the system while working through the modules. These findings suggest that internet connectivity and network issues affected their progress through the ITS. Many of the participants accessed the ITS on mobile devices and found the ITS slow on a mobile device and this may be the reason for the ITS freezing. This barrier may have been the reason for some of the lower scale ratings on the usability scale (e.g., Item: *The ITS AAC modules were easy to use*; $M = 4.0$; $SD = 1$; and Item: *It was easy for me to learn to use the ITS AAC modules*;

TABLE 2 ITS usability scale results.

Usability item	Not at all		Very much so			Mean	SD
	1	2	3	4	5		
The ITS AAC modules were easy to use	2.5%	5%	23.75%	31.25%	37.5%	4.0	1
It was easy for me to learn to use the ITS AAC modules	2.5%	1.25%	15%	32.5%	46.25%	4.2	1.9
I enjoyed learning using the ITS AAC modules	3.7%	1.2%	11.1%	13.6%	70.4%	4.5	0.9
If I made a mistake using the ITS AAC modules, I could correct my mistake easily and quickly	2.5%	1.25%	11.25%	27.5%	57.5%	4.4	0.8
The ITS AAC modules adequately showed me how I was progressing	1.25%	1.25%	10%	22.5%	65%	4.5	0.7
The IT system was easy to navigate	1.25%	2.5%	12.5%	28.75%	53.75%	4.3	0.9
The navigation was consistent when moving between screens and pages	1.25%	3.75%	10%	31.25%	52.5%	4.3	0.9
The help section for the ITS AAC modules was easy to use	2.5%	1.3%	10.1%	24.1%	60.8%	4.4	0.9
The help section for the ITS AAC modules was able to solve the challenges I had	1.25%	3.75%	18.75%	17.5%	57.5%	4.3	1.0
I would like to use an ITS for learning again in the future	2.5%	1.3%	7.6%	15.2%	73.4%	4.6	0.8
The AAC content was at the right level for me to understand it	0%	0%	10%	21.25%	66.25%	4.5	0.8
The information in the ITS AAC modules was well organized	1.25%	1.25%	3.75%	22.5%	72.5%	4.7	0.6
There was enough content on each of the topics for me	1.25%	1.25%	7.5%	33.75%	57.9%	4.5	0.7
The case studies in each module helped me to apply the knowledge I had learned	1.25%	1.25%	11.25%	18.75%	68.75%	4.6	0.7
The extra readings and resources were useful	1.25%	1.25%	6.25%	20%	72.5%	4.6	0.7
The amount of time involved in using ITS AAC modules has been right for me	2.5%	2.5%	7.5%	23.75%	61.25%	4.4	0.9

Note: AAC, augmentative and alternative communication; ITS, intelligent tutoring system.

$M = 4.2$; $SD = 1.9$). A second theme that was identified as a facilitating factor of learning was the practical nature of the training. Specifically, the use of case studies was identified as positive for participants to apply content learned practically. This corresponds with the high ratings on the usability scales (e.g., *The case studies in each module helped me to apply the knowledge I had learned*; $M = 4.6$; $SD = 0.7$). However, a barrier identified was system expectations of verbatim responses to questions posed by the ITS as part of the tutoring process. When providing answers to questions related to the case studies while working through the AAC modules, the ITS did not identify differently phrased, yet correct, answers, although it was programmed to do so through natural language processing. This made it challenging for the students to show their understanding and application of the content learnt in the module. The final theme regarding facilitators of the learning experience was the content of the modules, which was perceived as interesting, rich, and brief. This lines up with participant ratings on the usability scale ranging from 4.3 to 4.7 on these items. A barrier related to this theme, however, was that there were too many questions included in the ITS tutoring process to address the content. Examples of these facilitators and barriers as identified by the participants are shown in Table 3.

Knowledge regarding AAC

The pre- and post-test questionnaires assessed participants' knowledge of AAC. The raw scores for some items were very high (e.g., 97.3%, 98.2%, 92.8% correct), while it was low for others (e.g., 9.9% correct). Some items showed a balance between correct and incorrect answers (e.g., 55.9%, 65%, 54.1% correct). When scores were high on pre-test items, scores for these items were also high for the post-test. The same was true for items where low and mixed scores were achieved. Results showed statistically significant differences for some of the items, including:

- Module 1, Question 3 (Unaided AAC): $p = 0.016$; $d = 0.247$.
- Module 1, Question 4 (Low tech AAC): $p = 0.007$; $d = 0.282$.
- Module 2, Question 10 (AAC selection): $p < 0.001$; $d = 0.400$.
- Module 3: Question 12 (Types of communication partners): $p = 0.003$; $d = 0.317$.
- Module 3, Question 13 (Communication partner expectations): $p = 0.042$; $d = 0.199$.
- Module 4, Question 19 (Home literacy): $p = 0.035$; $d = 0.208$.



TABLE 3 Themes related to perceptions regarding the AAC curriculum and ITS.

Facilitator	Examples of facilitator	Barrier	Examples of barrier
Ease of use	<p>‘They were simple and easy to understand’ (participant 4)</p> <p>‘The way the content is explained in such an easy manner’ (participant 7)</p> <p>‘The modules were arranged in systematic manner which made them easier to handle’ (participant 16)</p>	System problems	<p>‘Sometimes the system could not allow me to proceed to the next question for days and it was very frustrating’ (participant 53)</p> <p>‘The system is very frustrating at some point the arrow refuses to take you to the other page hence one needs to start a fresh again’ (participant 62)</p> <p>‘The system kept crashing. I have to admit that I was very frustrated at one point’ (participant 72)</p>
Practical	<p>‘The examples inform of case studies made it easy for me to understand and apply in a real situation’ (participant 11)</p> <p>‘It was practical’ (participant 37)</p> <p>‘They involved case studies which made the lessons practical’ (participant 79)</p>	System expectation of verbatim answers	<p>‘Sometimes when answering the quizzes, the system marks my answers wrong yet provides an answer similar to mine but that differs may in a few words’ (participant 7)</p> <p>‘Inability of the system to recognise answers that are phrased differently’ (participant 35)</p> <p>‘In some of the quizzes my answers would be marked wrong just because they differ slightly from the ones provided by the system’ (participant 21)</p>
Content	<p>‘The modules had interesting information about AAC’ (participant 17)</p> <p>‘They were brief and rich in content’ (participant 55)</p> <p>‘Rich content’ (participant 35)</p>	Number of questions asked	<p>‘The questions were too many’ (participant 9)</p> <p>‘There are so many questions’ (participant 26)</p> <p>‘The questions given per module were a lot’ (participant 69)</p>

Abbreviations: AAC, augmentative and alternative communication; ITS, Intelligent Tutoring System.

A small effect size was obtained for most of these questions. These results are shown in Table 4. Modules 1–3 all showed statistically significant differences with small effect sizes. Table 5 shows the results per module. Overall, there was a statistically significant difference between the pre- and post-test. This indicates that knowledge of AAC improved after working through the AAC curriculum on the ITS.

DISCUSSION

This study aimed to determine whether the use of an ITS is a feasible way in which to train students in Africa in AAC. Overall, the use of an ITS appears to be a feasible means of providing online teaching to students across Africa. Despite the concerns about implementing online learning in Africa due to limited, unreliable and costly internet and challenges accessing technology in resource-constrained settings (Krohn et al., 2021; Mathew & Iloanya, 2016), this study indicates that the participants could learn, using the technology available to them. The ITS provided a low-data learning option that was accessible to students across Africa. The system itself, as well as the content of the modules, were generally perceived as easy to use and facilitated a systematic manner of gaining knowledge in AAC.

The learning experience was perceived as practical with rich content. The use of an ITS can therefore be considered for implementation in the African context.

The development of a valid curriculum was ensured by recruiting specialists in the field of AAC, specifically in Africa. By grouping specialists into teams, each module was developed by those with clinical experience in AAC, as well as by those with experience with lecturing students and researching current trends in AAC. Additionally, a transdisciplinary model ensured that different professionals involved in the implementation of AAC compiled the AAC curriculum. Involving relevant stakeholders in the development of the curriculum is essential in ensuring that the curriculum is practical and acceptable to those implementing it (Luesse & Contento, 2019). Stakeholders working in the field could provide their expertise related to the practical application of AAC in the African context. Stakeholders in the academic field could provide their educational expertise, which included guidance in the thinking processes of students which directed the development of the tutoring prompts. The stakeholders applied their insights about the needs of students in Africa as well as their knowledge and capacity to tailor the development of the curriculum. This ensured an appropriate curriculum, which was practical, evaluable, suitable and affordable (Luesse & Contento, 2019). This is reflected in

TABLE 4 Pre- and post-test results of AAC knowledge per question.

Question	Topic covered	Significance $p < 0.05$	Effect size Cohen's D
Module 1: Overview of AAC			
Question 1	The purpose of AAC	0.363	0.040
Question 2	Modes of communication	0.500	0.000
Question 3	Unaided AAC	0.016**	0.247*
Question 4	Low tech AAC	0.007**	0.282*
Question 5	High tech candidacy	0.170	0.109
Module 2: Assessment for Participation			
Question 6	Goal of an assessment	0.081	0.160
Question 7	Language development and AAC candidacy	0.127	0.130
Question 8	Assessment of activities	0.500	0.000
Question 9	Assessment of environment	0.276	0.068
Question 10	AAC selection	< 0.001**	0.400*
Module 3: Communication Partners in AAC			
Question 11	Communication partner perceptions	0.329	0.050
Question 12	Types of communication partners	0.003**	0.317*
Question 13	Communication partner expectations	0.042**	0.199
Question 14	Success of communicative exchanges	0.343	0.046
Question 15	Communication partners skills	0.500	0.000
Question 16	Communication partner training	0.500	0.000
Module 4: Literacy in AAC			
Question 17	Illiteracy in Sub-Saharan Africa	0.178	0.105
Question 18	Core vocabulary	0.099	0.147
Question 19	Home literacy	0.035**	0.208*
Question 20	Phonetically regular words	0.105	0.143
Question 21	Memory books	0.383	0.034
Total score		< 0.001*	0.364

Notes: AAC, augmentative and alternative communication.

** $p < 0.05$ Cohen's $D > 0.2$ = small effect*; > 0.5 = medium effect; > 0.8 = large effect.

TABLE 5 Pre-test and post-test results of AAC knowledge per module.

Module	Pre-test mean	Post-test mean	Significance $p < 0.05$	Effect size Cohen's D
Module 1: Overview of AAC	51.8%	58.4%	0.010**	0.268*
Module 2: Assessment for Participation	57.7%	64.6%	0.011**	0.267*
Module 3: Communication partners in AAC	40.6%	45.2%	0.008**	0.277*
Module 4: Literacy in AAC	43.8%	47.1%	0.150	0.118
Total	48.3%	53.5%	< 0.001*	0.364

Notes: AAC, augmentative and alternative communication.

** $p < 0.05$ Cohen's $D > 0.2$ = small effect*; > 0.5 = medium effect; > 0.8 = large effect.

the overall positive perceptions of the ITS and the AAC curriculum.

The pre-/post-test assessment showed an overall change in knowledge after working through the AAC curriculum

using the ITS. The developed AAC curriculum can therefore be considered suitable for developing knowledge in AAC and the ITS can be considered a feasible method of delivering such a curriculum in the African context. This

is in line with the meta-analysis by Ma et al. (2014), which found that the ITS were effective in facilitating learning. The use of the ITS AAC curriculum can therefore be seen as a suitable tool for providing knowledge on AAC.

As not all the questions demonstrated significant differences in knowledge at pre- and post-test assessment, the content requires careful consideration. Given that disciplines like AAC typically require practical experiences and specialized training to acquire the necessary knowledge and skills, training via an online environment presents professionals, the module, and ITS designers with considerable challenges (Castro & Tumibay, 2021). The case study design employed in this study provided the participants with a learning context with real-world examples and the kinds of activities that would be relevant for professional practice. The incorporation of case study instructional design also allowed the participants to learn at their own pace and at a time that suited their schedules. While the design of the ITS was intended to provide interactive learning, the limitations of the ITS could have influenced the limited changes in knowledge in some of the questions. It could benefit participant learning to incorporate multi-media input such as videos to improve their engagement and interaction with the modules. Further research is required to understand how the use of multi-media supports in the ITS, considering resource constraints, can facilitate participants' learning while using limited data and possibly not requiring the students to be connected to the internet. For example, in the postgraduate teaching programme offered by the (removed for review), the involvement of the instructors allows for scaffolded, self-directed, and group learning opportunities that support collaboration and interaction between the students. This could be explored as additional support to the ITS in future iterations of the system.

Other work investigating usability testing of an ITS has shown that usability and learning effectiveness are closely connected (Chughtai et al., 2015; Lin et al., 2014). Since the ITS expectations of verbatim answers were identified as a source of frustration and a major challenge for participants, this experience could have impacted how the participants answered and meant that their focus shifted from the content to answering what the ITS would mark as correct. It certainly could have lowered their engagement with the module content. This is a possible reason for the lack of statistically significant changes across some of the individual module questions. Future refinement of the natural language processing of the ITS is required.

The results from the study can be seen as an initial step in exploring the use of alternative methods of teaching to facilitate the development of knowledge in the field of AAC and possibly for related fields such as the education and medical fields. An ITS shows potential applications for

low-resource contexts in Africa for undergraduate training in higher education facilities and, in the long-term, with further research supporting it, for practicing professionals. Practical considerations need to be placed at the forefront of future, improved ITS design. There is a need for mobile-friendly systems as most students will use this format to access the system. Even though data usage was not highlighted as a major concern for the participants in this study, it should be considered for future ITS refinement and design. This most likely would have had an impact on their engagement and interaction with the modules and could have influenced their attitudes towards the content, impacting their learning from the ITS.

Despite the challenges experienced, the AAC curriculum could be successfully implemented using the ITS with the technology available to the participants. Results obtained in this study can be used to further refine and revise the AAC curriculum and ITS.

LIMITATIONS OF THE STUDY

A limitation of this study is the use of a single-group pre- and post-test design without a control group. This makes it challenging to attribute improvements in knowledge to the AAC modules. A control group would strengthen the validity and credibility of the results of the study (Marsden & Torgerson, 2012). Future research in the implementation of the ITS should use an experimental or quasi-experimental design which includes a control group. A second limitation is that differences between participants were not considered. Participants were included based on their enrolment in programmes at participating universities and factors such as year of study, home language and age were not specified, resulting in a heterogeneous population. A more specific participant sample, with more defined inclusion criteria, is recommended for a more controlled study (Garg, 2016). Additionally, although changes in knowledge of AAC were noted, this does not necessarily translate to changes in clinical skills in AAC. Future research should consider how the training modules impact clinical skills in AAC. Furthermore, further research on the use of the ITS AAC modules in different contexts, with other populations, such as parents or qualified AAC professionals is recommended.

Finally, the level of proficiency in digital literacy was lower than expected from students while navigating the ITS. The participants seemed to struggle with understanding and navigating the interface. At times, the researchers had to guide the participants step by step through the process of using the ITS, showing them, for example, how to first sign up to the system before being able to log in to the ITS. Despite receiving a help guide explaining the various

aspects of the ITS, many participants required one-on-one assistance. Changes to the ITS were also made during the implementation phase to assist the participants, such as adding password specifications to the sign-up page and adding a 'quick navigation' function to make navigating through the ITS easier. A system should be user-friendly for average users to navigate. When users spend considerable time learning how to use and navigate a system, this suggests that a system could benefit from quality usability improvements (Chughtai et al., 2015). A final limitation of this study is, therefore, that the system may have been challenging for the students to navigate. Future implementation of the ITS for AAC in the African context should ensure that personal support can be provided to students, as needed, to optimize their engagement with the ITS and prevent unnecessary frustration.

CONCLUSIONS

This study can be seen as a first step in understanding the effects of using an ITS to facilitate the development of knowledge and critical thinking skills in the field of AAC. Overall, the ITS was positively perceived by the participants. This feasibility study shows that the ITS may be an effective means of providing training in AAC to university students, although refinement of the ITS is still required. System modifications, such as improvement of the natural language processing of the ITS, would reduce frustrations experienced when using the ITS and increase the effectiveness of the training.

The potential to deliver effective AAC training to professionals in a way that is accessible, affordable and context-appropriate despite constraints such as remote locations, limited number of trainers, time constraints and limited connectivity holds great promise for the field of AAC. While the application in LMICs seems obvious, AAC service provision remains unequal even in high-income countries. An ITS-facilitated AAC training programme can level the playing field and ensure more equitable access to AAC training. Improved knowledge gained from such training opportunities will facilitate AAC service delivery in resource-constrained contexts and probably non-resource-constrained contexts as well... possibly improving access to AAC services.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest. The authors alone are responsible for the content and writing of the paper.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the authors upon request.

PARTICIPANT CONSENT STATEMENT

All participants provided written informed consent prior to enrolment in the study.

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