An Intelligent Tutoring System for Improving Adult Literacy Skills in Digital Environments

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Abstract

Twenty-first century literacy includes a mixture of digital and print literacy skills and strategies. AutoTutor for Adult Reading Comprehension is a web-based intelligent tutoring system that is designed to help adult learners develop effective reading comprehension strategies. Lessons span basic reading skills (vocabulary, word parts), comprehension of sentences and texts in different text genres and rhetorical structures, including digital documents and media. The AutoTutor system features an accessible interface, conversational trialogues with helpful and engaging computer agents, and material and scenarios that were developed specifically for adult learners. Studies suggest that this system significantly improves learning outcomes when used in conjunction with classroom instruction. Materials described in this article are free and readily available to adult educators and their students.

Overview

Opportunities for adults to read and write are rapidly and increasingly taking place in a hybrid of digital and print environments. As a result, adults with inadequately developed literacy skills face a complex set of challenges. Not only must they develop traditional reading and writing abilities; they must do so in the context of navigating and problem-solving in digital environments. These environments call upon additional sets of skills (Frank & Castek, 2017). When adults who struggle with reading comprehension also lack digital skills, their ability to fully utilize educational technology and gain practical literacy experience decreases substantially. This poses a unique challenge to educators. Since reading, writing, and digital skills are now co-dependent in many ways, adult literacy programs would ideally help learners to co-develop their skills in order to equip them to participate in evolving literacy environments (Magliano et al., 2017). This article describes **AutoTutor for Adult Reading Comprehension** (AT-ARC, available at arcweb.us), a conversation-based, intelligent tutoring system designed to support the development of reading comprehension skills in adults, including lessons that highlight computer and internet/web-specific reading strategies.

AutoTutor is a family of intelligent tutoring systems that have been shown to promote beneficial learning outcomes in multiple domains (Graesser, 2016; Nye et al., 2014). AT-ARC is an extension of this system that targets adult reading comprehension strategies (Graesser et al., 2019). It was developed at the Institute for Intelligent Systems at the University of Memphis through a series of federal grants. AT-ARC contains 30 lessons arranged in three categories: *words and sentences*, *computer and internet*, and *stories and text*. These lessons promote reading at levels ranging from individual words and word parts to complex passage and digital scenario comprehension. Lessons typically take 20-50 minutes to complete and, like other intelligent tutoring systems, are designed to adapt to students' performance.

AT-ARC lessons were built to align with empirically motivated adult education content standards (Pimentel, 2013). Adult learners using AT-ARC as a supplement to regular teaching have been shown to increase comprehension scores on psychometric tests of comprehension for most clusters of adult readers (Fang et al., 2018). Three features distinguish AT-ARC as a uniquely beneficial tool for adult literacy education. First, AT-ARC accommodates most levels

of digital and reading skills by employing a low-demand, accessibility-focused interface and straightforward instructional design. Second, learning is promoted using a *trialogue* design with two conversational computer agents (a tutor and a peer) that interact, instruct, and model learning for students. Finally, AT-ARC approaches literacy from an adult-focused framework that recognizes the need for digital and internet skills as essential components of adult literacy education. By examining each of these features in detail, we hope to encourage the use of AT-ARC by educators seeking to supplement their adult literacy curricula, and by students seeking to further their literacy skills. AT-ARC is free, ready for use, and currently available at arcweb.us. Further, through a federal grant, users are contributing to the research, development, and enhancement of the system's effectiveness for the adult education community.

User-friendly interface and straightforward instructional design

Web-based educational technologies must account for all levels of digital skill levels in adult learner populations in order to be accessible and beneficial to learners with low skill levels. The interface design of AT-ARC is empirically grounded in studies that have examined the prevalence of specific computer skills in adults who participate in adult literacy education programs (Olney et al., 2017). Accordingly, AT-ARC most often employs point-and-click (or touch), multiple-choice, and drag-and-drop interactions. Further, each time a new computer skill is required, such as clicking, typing, or scrolling, learners are presented with a short, repeatable tutorial that demonstrates and allows for practice and acclimation. While keyboard use is minimized, some open-ended writing sections are used to help the system adapt to the needs and skills of the student. Digital interfaces are constantly changing, as is the familiarity of features and functions in the population. Our R&D team is also continuously adapting and researching user design to incorporate new features/functions and provide tutorials to learners to enhance their digital skills in concert with their comprehension skills.

Most lessons begin with short tutorial videos that engage the learner and give a brief overview of the lesson topic, which can be accessed at any point during the lesson. After this overview, computer agents briefly introduce and explain reading strategies relevant to the lesson by conversing between themselves. This conversation can always be repeated before moving on. Task instructions are presented in text, with an option to have the text read aloud by pressing a button in order to accommodate struggling readers. Reading material is often accompanied by visual aids, including pictures, diagrams, and multimedia presentations that facilitate comprehension and increase learner engagement.

Trialogue interactions

Throughout their experience with AT-ARC, learners are accompanied by two computer agents that converse with the student and each other. This three-way conversational structure is known as a *trialogue*. Studies involving conversational trialogues have demonstrated that these interaction systems have features that have advantages over dialogue and monologue systems, such as the two agents modeling social interactions (Graesser et al., 2017). In addition to serving instructional and read-aloud functions, the agents' expansive and adaptive conversations provide scaffolds for learning. The agents demonstrate how to apply learning strategies in order to create deeper understandings of text and digital scenarios. In many lessons, one agent takes the role of a

teacher, while another takes the role of a peer student. In these scenarios, the learner and the peer agent both attempt to answer questions posed by the teacher agent. This occasions the opportunity for the learner and peer agent to agree or disagree in any combination of correct or incorrect responses. When the learner responds correctly and the peer agent responds incorrectly, the teacher agent explains why the correct response is the best answer to the question, and how and why the peer agent's response is incorrect. If the learner does not respond correctly, they are given some additional information from the agents to help them try to answer again. In this way, the adaptive, conversational trialogue helps guide the learner through reading comprehension strategies in each lesson, while providing scaffolds for learning based on peer modelling.

Conversational trialogues were designed to increase engagement and motivation compared with intelligent tutoring designs without agents (Graesser et al., 2017). Learners also can enter their names into the system, allowing the agents to address them accordingly, personalizing the learning experience and creating a more conversational environment. When the agents take the roles of teacher and peer, they can provide encouragement, guidance, and support from multiple perspectives. To increase and sustain engagement, the agents sometimes arrange friendly competition between the learner and peer agents, awarding points for correctly answered questions, including additional points for more difficult questions. These competitions adapt to the learner's performance such that the learner always eventually wins, which is designed to support self-efficacy, confidence, and engagement.

Adult learner-oriented environments

Adult learner populations have rich and diverse histories with language, literacy, and education experience, especially compared to skill-matched child learners. Research also shows that adults with low literacy use cognitive reading component skills and strategies differently than children who read at the same level (Binder et al., 2019; Sabatini et al., 2019). Teaching adults comprehension skills using materials developed for children is less optimal in comparison to using materials that account for and accommodate the rich and diverse characteristics of adult learner populations. This is especially true considering the stakes of the digital environments that adults must navigate, including career-based and financial contexts.

Accordingly, AT-ARC is specifically designed to engage adult learner populations. Further, because each lesson is built to align with the College and Career Readiness Standards for Adult Education (Pimentel, 2013). This content builds skills that support success and engagement in postsecondary education, the workplace, and civic responsibilities. Lessons address practical applications of literacy skills, such as filling out electronic job forms and rental agreements, researching topics using the internet, and using email and social media. To account for the wide variety of skill and experience in adult learner populations, AT-ARC adapts to the strengths and weaknesses of each learner, enabling challenging learning opportunities to those who demonstrate proficiency, and providing foundational guidance for those who struggle with a given lesson. Additionally, the conversational agents that guide the learner throughout their experience are oriented to support and engage adult learners.

Using AT-ARC

AT-ARC is free and available at arcweb.us. The system allows for educators to request a "teacher" account that lets them administer AT-ARC lessons to learners with associated "student" accounts. Student registration is designed to demand as little as possible of the registrant. Detailed instructions for creating teacher accounts and registering students are available and accessible from the home page. Once students begin taking lessons, teachers can track their performance in order to understand the strengths, weaknesses, and progress of individuals across each lesson.

As noted, research has shown significant comprehension learning gains when using AT-ARC as a supplement to regular teaching (Fang et al., 2018). It is recommended that educators using AT-ARC should determine the best frequency of use based on the needs of their students. Tailored configurations to fit teacher/classroom structure or learner differences is encouraged. For example, lessons can serve as foundational content to tutoring sessions, provide a means of demonstrating knowledge gained from other sessions, or function as auxiliary exercises to complement related content. While the lessons are arranged in a loose order from foundational to complex, they may be taken individually and in any order. In this way, teachers and students of AT-ARC can take advantage of its adaptability to achieve the maximum possible benefit for every adult learner.

Instructional guides, lesson demonstrations, and signup information can be found on the home page (arcweb.us). The goal of the AT-ARC project is to effectively help adult learners develop modern literacy skills. We hope to encourage the use of AT-ARC in the adult education community as we continue to research and develop its effectiveness as a tool for adult educators.

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