The Adaptive Features of an Intelligent Tutoring System for Adult Literacy

Genghu Shi[1]([✉]), Lijia Wang[1], Liang Zhang[1], Keith Shubeck[1], Shun Peng[2], Xiangen Hu[1,2], and Arthur C. Graesser[1]

[1] The University of Memphis, Memphis, TN 38152, USA
gshi@memphis.edu
[2] Central China Normal University, Wuhan 430079, Hubei, China

Abstract. Adult learners with low literacy skills compose a highly heterogeneous population in terms of demographic variables, educational backgrounds, knowledge and skills in reading, self-efficacy, motivation etc. They also face various difficulties in consistently attending offline literacy programs, such as unstable worktime, transportation difficulties, and childcare issues. AutoTutor for Adult Reading Comprehension (AT-ARC), as an online conversation-based intelligent tutoring system that incorporated a theoretical model of reading comprehension, was developed with great efforts to meet adult learners' needs and be adaptive to their knowledge, skills, self-efficacy, and motivation. In this paper, we introduced the adaptive features of AT-ARC from four aspects: learning material selection, adaptive branching, trialogues, and interface, as well as the rationale behind these designs. In the end, we suggested further research on improving the adaptivity of AT-ARC.

Keywords: Adult literacy · Intelligent tutoring system · AutoTutor · Adaptivity

1 Introduction

Research shows that literacy proficiency and the ability to use computers are positively related to one's success in finding jobs with relatively higher salary [2, 16]. It also has been documented that literacy proficiency is one of the strongest factors that influence the problem-solving in computer-based environments [17]. Following this logic, literacy should be one's basic skills in modern life. However, one in six adults in the United States have low levels of literacy skills [16]. It has a negative impact on the social health and economic stability of the entire country as well as the personal well-beings [16, 20]. Most literacy programs are not designed to be adaptive to the needs and characteristics of adult learners with low literacy proficiency but for K-12 students because they have a higher priority. And, the existing adult literacy programs, which are often funded by government or non-profit organizations, generally do not reach the level that can accommodate all adults in need. Moreover, it is difficult to teach comprehension strategies at deeper levels because few teachers and tutors in literacy centers are trained to cover these levels of reading difficulty.

1.1 Adult Learners

Adult literacy learners are a highly diverse population [4]. They can be varying not only in demographic variables (age, gender, and race/ethnicity), but also in terms of educational backgrounds, learning disabilities, and their native languages (English or other) as well as their motivation for taking part in adult literacy courses [14]. They also have many difficulties in consistently attending offline literacy programs, such as unstable work time, transportation difficulties, and childcare issues [1, 12, 21]. It is very difficult for a face-to-face literacy program to overcome all these difficulties and adapt to the heterogeneity of the adult learners.

Computer-based instructional systems, especially intelligent tutoring systems, can easily cope with the difficulties the adult learners face in learning. For example, intelligent tutoring systems usually deliver well-fabricated instructions online [9]. Thus, they can be easily accessed by adult learners using digital devices with internet connection anytime and anywhere. Meanwhile, intelligent tutoring systems are generally aligned with theories from cognitive psychology, education, and learning sciences [9]. They also use algorithms to recommend individualized learning contents, strategies, and paths to different learners based on their current knowledge levels, needs, goals, aptitudes, and even personality. We developed a conversation-based intelligent tutoring system, AT-ARC, to help adult learners with low literacy skills to improve their deep levels of reading comprehension in English language. Our system supports adult learners who read at grade levels from 3.0 to 8.0 or equivalent. Massive work has been done by our research group to tailor the instruction and learning materials to meet the various needs and characteristics of the adult learners. Before introducing AT-ARC, we will first learn about prototype of it, AutoTutor.

1.2 AutoTutor

AutoTutor is a conversation-based intelligent tutoring system which supports a mixture of vicarious learning and interactive tutoring [15]. Both instruction modes are modeling the behaviors of a typical human teachers when they are giving lectures in class [15]. Vicarious learning is implemented in the Information Delivery mode in which human learners learn from the didactic information provided by the tutor agent as well as the observation of the tutor agent promptly answering deep questions asked by peer agents [2]. During interactive tutoring, human learners answer a main question by interacting with the tutor agent in natural language. The dialogue pattern during this process is called expectation and misconception tailored dialogue (EMT dialogue) which can be commonly observed from the interactions between human tutors and learners [8]. Each main question is associated with a list of expectations (anticipated good answers, steps in a procedure) and a list of anticipated misconceptions (bad answers, incorrect beliefs, errors, bugs). As the learners express their answers over multiple conversational turns by typing, the information they provide is compared with the expectations and misconceptions using both a latent semantic analysis tool and regular expression (Regex). AutoTutor gives positive (e.g., "Great answer"), neutral (e.g., "I see", "Uh huh!"), or negative (e.g., "Not really", "Not quite") feedback to the learner based on the quality of the answers, pumps the learner for more information (e.g., with the question "What

else?"), prompts the learner to fill in missing words, gives hints to direct the learner to answer the main question, fills in missing information with assertions, identifies and corrects bad answers, answers learners' questions, and summarizes answers at the end of dialogue turns.

Below is an example of EMT dialogue that illustrates the discourse patterns between the computer tutor and a human student.

(1) **TUTOR**: Please read the following text. [Request for student to read]
(2) **STUDENT**: [Student reads the text about the steps to change a blown tire]
(3) **TUTOR**: Very good. [Positive short feedback] What is the topic of this text? [Prompt]
(4) **STUDENT**: About changing a tire.
(5) **TUTOR**: Right. [Positive short feedback] About changing a blown tire. [Prompt completion] What is the first step when you find one your car tire is blown? [Question]
(6) **STUDENT**: I don't know.
(7) **TUTOR**: What about this sentence? [Hint]
(8) **STUDENT**: It says to stop your car.
(9) **TUTOR**: Not really. [Short negative feedback] Where should you stop your car? [Prompt]
(10) **STUDENT**: Exit the freeway or pull the car over the road.
(11) **TUTOR**: Right. [Short positive feedback] If you drive on freeway, take the next exit to find a safe place. Otherwise, pull your car as far onto the shoulder as possible. [Prompt completion]
(12) **TUTOR**: Now let's recap what the instruction is saying… [Summary]

AutoTutor has been implemented in many domain areas, such as computer literacy, critical thinking, physics, electronics, and adult literacy. Empirical evidence shows that AutoTutor has produced learning gains of approximately 0.80 sigma (standard deviation units) on average when compared to non-interactive learning environments such as reading a textbook [7, 15]. AT-ARC is an instance of AutoTutor implemented in the domain of adult literacy. In the following, we will also describe implementation details and the theoretical model of AT-ARC, as well as the adaptive features of it from four aspects: learning material selection, adaptive branching, trialogues, and interface.

2 AT-ARC and Its Theory

AutoTutor for Adult Reading Comprehension (hereafter, AT-ARC) is an online intelligent tutoring system that help adult learners improve their reading comprehension skills. The system was deployed in a learning management system, Moodle (https://adulted.aut otutor.org), as well as a self-made website (https://read.autotutor.org) for public access. The data of AT-ARC is stored in a learning record store (Veracity Learning) which uses a standard (xAPI) to format the data. AT-ARC uses a tutor agent (Cristina) and a peer agent (Jordan) to deliver the 30 lessons. The two computer agents hold conversations with the human learner and with each other, which is called trialogue [8]. Each lesson focus on one or more reading skills in a theoretical model of comprehension [10].

2.1 AT-ARC Lessons

Each of the 30 lessons consists of instruction and practice sections. Within each lesson, the adult learners first receive a mini lecture about a reading skill that lesson tapped, then practice the skill by answering multiple choice questions related to words, sentences, texts, or visual information (such as text style and picture images). The number of questions in the AT-ARC lessons ranges from 6 to 30. In most lessons, when an adult learner answers a question incorrectly or does not provide a complete answer, they will receive hints from one of the two computer agents, providing a second chance with somewhat more guidance. It usually takes 20–50 min for an adult learner to complete a lesson.

The 30 curriculum lessons are categorized into 3 groups based on their modalities, that is, the forms of the learning materials. The three groups are *words and sentences*, *stories and texts*, and *computer and internet* (see Fig. 1). The lessons falling in the *words and sentences* category teach knowledge about words (word decoding and identification) and sentences (syntax). The *computer and internet* lessons teach knowledge about using computer and internet to file job applications, send emails, search information, and interact with people on social media sites. The *stories and texts* teach deep reading comprehension strategies related to lengthy entertaining, informative, or persuasive texts. The detailed description of each lesson is included in Table 1.
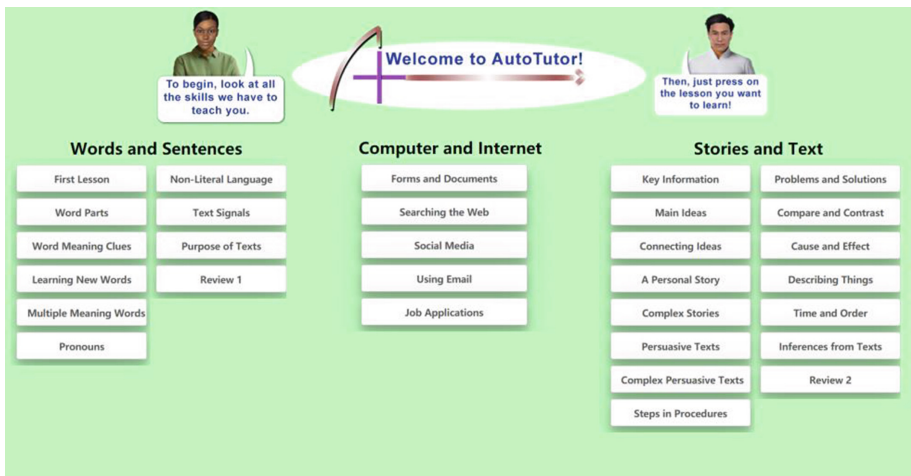

Fig. 1. AT-ARC lessons and their categories.

2.2 Theoretical Model of Comprehension

The design of AT-ARC curriculum also incorporated a theoretical model of reading comprehension which is proposed by Graesser and McNamara [10]. The theoretical model adopts a multicomponent, multilevel framework. Graesser and McNamara (2011) framework identifies six levels of reading comprehension components: words (W), syntax (S),

the explicit textbase (TB), the referential situation model (SM), the discourse genre and rhetorical structure (RS), and the pragmatic communication level (between speaker and listener, or writer and reader). We will specify the meanings and its components of each level. The pragmatic communication level is not tapped in AT-ARC curriculum. Therefore, it will be not introduced.

Words and Syntax. Words and syntax are lower levels basic reading comprehension skills. They consist of the reading components of morphology, word decoding and identification, word order, and vocabulary [19].

Textbase. The textbase level consists of the basic idea units or explicit meaning of the text but not necessarily the exact wording and syntax. These basic idea units include statements, clauses, or propositions.

Situation Model. The situation model (sometimes called the mental model) is the readers' mental representation of the subject matter of the source text. It requires readers to make inferences relying on world knowledge [23]. This situation model varies with the genres of texts. In narrative texts, situation model includes information about characters, settings, actions, and emotions. In informational text, it would contain more technical content (e.g., knowledge and inferences about automobiles when reading a maintenance document on a truck). AT-ARC lessons target on the strategies of using connectives (e.g., because, so that, however), adverbs (finally, previously), transitional phrases (in the next section, later on that evening), or other signaling devices (such as section headers) to build situation models.

Genre and Rhetorical Structure. Genre and rhetorical structure refers to the type of discourse and its composition. Genre refers to the type of discourse, such as narration, persuasion, exposition, and information, as well as their subcategories. For example, narrative encompasses folk tales and novels, whereas persuasive texts include newspaper editorials and religious sermons. The rhetorical structure of a text provides the differentiated functional organization of paragraphs. There are different rhetorical frames, such as compare–contrast, cause–effect, claim–evidence, and problem–solution [11].

The Table 1 shows the alignment of the theoretical levels with the 30 lessons. And the labels and description of the lessons can imply the reading components they tapped.

Table 1. AT-ARC lessons and alignment of theoretical levels and description. (W = Word; S = Syntax; TB = Textbase; SM = Situation model; RS = Genre and rhetorical structure)

Lesson name	Theoretical levels	Description
First lesson		Learn how to use AutoTutor.
Word parts	W	Learn how words are created from parts of words, such as roots, prefixes and suffixes.
Word meaning clues	W	Learn how visual and letter clues can help you learn the meaning of a word.
Learning new words	W	Learn how the meaning of new words can sometimes be figured out by the words and sentences before and after the word.
Multiple meaning words	W, S	Most words have multiple meanings. Learn how to detect the best meaning of a word in a text from the words and sentences before and after the word.
Pronouns	TB, W	Learn about pronouns (such as he, she, and it). Figure out what person, place, thing, or idea a pronoun refers to in a text.
Non-literal language	SM	Sometimes the author's meaning is different from the literal meaning of the words. Learn how to identify non-literal language and figure out its meaning in texts.
Text Signals	SM	Learn about the role of visual information (such as text style and picture images) in helping you understand a text.
Purpose of texts	RS	Learn how to identify texts that are stories (narrative), persuasion, versus informational.
Review 1	SM, W	Review the reading strategies learned from the previous lessons in words and sentences.
Forms and Documents	SM, TB	Learn how to read documents and fill out forms in real life.
Searching the web	SM, W	Learn how to search the Internet for information.
Social media	SM, RS, TB	Learn how to use social media, such as Twitter and Facebook.
Using email	SM, TB, RS	Learn how to receive, read, write, and send email messages.
Job applications	SM, RS, TB	Learn how to write your job resume.

Table 1. (*continued*)

Lesson name	Theoretical levels	Description
Key information	TB, SM	Learn about the differences between stories (narratives), informational, and persuasive texts.
Main Ideas	TB, RS	Learn how to identify the topic and main ideas in a text.
Connecting ideas	SM, TB, RS	Learn how to connect the characters, setting, and plot in a story.
A personal story	SM, TB, RS	Learn how to make inferences and ask important questions about a personal story.
Complex stories	SM, TB	Learn how to make inferences and ask questions about complex stories.
Persuasive texts	TB, RS	Learn how to evaluate a persuasive text by identifying the topic, main arguments, and supporting information.
Complex persuasive texts	SM, TB	Learn how to understand complex persuasive texts.
Steps in procedures	RS, TB, SM	Learn how to read texts that describe steps in a procedure, such as changing a car tire.
Problems and solutions	RS, TB, SM	Learn how to identify problems and solutions in texts that solve problems.
Compare and contrast	RS, TB, SM	Learn how to identify similarities and differences in texts that make comparisons.
Cause and effect	RS, TB, SM	Learn how to identify causes and effects in science texts.
Describing things	RS, TB, SM	Learn about texts that describe people, places, things, or events.
Time and order	RS, TB, SM	Learn about texts that order events in time or ideas in importance.
Inferences from texts	SM, TB	Learn how to make inferences in informational texts.
Review 2	SM, TB, RS	This lesson is a review on previous lessons in stories and texts.

3   Adaptive Features of AT-ARC

Massive work has been done by the AT-ARC research group to tailor the instruction and learning materials to meet the various needs of the adult learners and adapt the interface and interactive features to their characteristics. This section describes the adaptive features of it from four aspects: learning material selection, adaptive branching, trialogues, and interface.

3.1   Learning Material Selection

The 30 lessons were carefully scripted to contain learning materials (words, sentences, and texts) that have practical values that are adaptive to the adult learners' needs in their daily life. For example, the learning materials were selected to help adult learners learn knowledge about words (e.g., Word Parts, Multiple Meaning Words, Learning New Words, etc.), read rental agreements, fill job applications (e.g., Forms and Documents), figure out the procedure of recipes or changing a tire (Steps in Procedures), search for health information (e.g., Searching the Web), etc. These materials are expected to interest adults.

The adult learners often read at a grade level of 3 to 7.9. The learning materials in the AT-ARC lessons were selected to be adaptive to the adult learners' zone of proximal development [22]. According to *Goldilocks principle*, the words, sentences, and texts were selected to be at the adult learners' reading level that they can handle (not too hard or too easy), so that they do not become frustrated or get bored. For example, the texts were selected based on their difficulty levels (i.e., grade levels) that were measured by Coh-Metrix, a system that scales texts on difficulty by considering characteristics of words, syntax, discourse cohesion, and text category [6].

3.2   Adaptive Branching

Most of the 30 lessons have easy, medium, versus difficult learning materials (words, sentences, and texts) measured by Coh-Metrix [6]. Within the practice section of a lesson, the adult learners start with practice questions pertaining to words, sentences, or a text at the medium level of difficulty. Depending on their accuracy on these questions, the adult learners receive questions pertaining to either easier or harder learning materials. That is, higher accuracy on the questions of medium learning materials leads the adult learners to the more difficult branch of learning materials, whereas lower accuracy leads to the easier branch.

When an adult learner answers a question correctly at the first attempt, he/she gets full credit for answering the question. When the adult learner answers the question incorrectly, AT-ARC adaptively generates a hint with some instructional information based on the incorrect choice the adult picked and gives the adult a second chance; the adult gets partial credit when the answer is correct on the second attempt. The wrong choice selected indicates the adult learner's misconception about the question. If the adult fails at the second try, AT-ARC announces the correct answer and explain why it is correct.

3.3   Trialogues

The AT-ARC uses two computer agents to deliver the EMT trialogue. The tutor agent is named *Cristina* and the peer agent's name is *Jordan.* Trialogues can be designed in different ways.

1) ***Vicarious learning with human observation or limited participation.*** The adult learner can observe the tutor agent interacting with the peer agent or have limited

participation. This is known as vicarious learning which has instructional purpose. This form of trialogues particularly benefit the low skilled learners. The occasional participation of the adult learner can promote their engagement. For example, the mini lecture at the beginning of each lesson takes this form of trialogue.

2) *Human interacting with the two computer agents.* The tutor agent interacts with the adult learner and the peer agent with tutorial dialogues. The adult learner contributes and receives feedback. The peer agent adjusts its knowledge and skills according to the learner's skill level. When the adult is a skilled learner, the peer agent usually gives correct answers. When the adult leaner has lower skills, the peer agent takes the criticism by picking the same bad answer as the human learner. This is an approach designed to help adult learners build self-esteem and a sense of self-efficacy. Then two computer agents can also express contradictions, arguments, and different views. These discrepancies stimulate cognitive conflicts, confusion, and potentially deep learning, but this may be beyond the adult learners' zone of proximal development.

3) *Human teaching/helping peer agent with the facilitation of tutor agent.* The adult learner can also teach or help the peer agent with the facilitation of the tutor agent. High skilled learners benefit from this kind of trialogue. For example, Jordan asks for help from Cristina and the adult learner to get familiar with social media use. Cristina always brings up questions for human learner to answer. When the adult learner is correct, the peer agent expresses his appreciation. When the adult learner is wrong, the tutor agent generates hints and gives the adult learner another chance or reveals the correct answer and explain why.

4) *Tutor agent staging a competition between the human and a peer agent.* The tutor agent can guide a competition between a human learner and the peer agent, in which the adult learner and a peer agent takes turn to answer questions that the tutor agent asks. This competitive game may promote the motivation of human learners.

Here is an example trialogue between Cristina, Jordan, and an adult learner. The trialogue happens in the lesson shown in Fig. 2.

(1) **Cristina (tutor agent):** Okay, why might the writer want to go back to school to get a GED, based on what you read in this text? [Main question]
(2) **Adult Learner:** [Pick the first choice] The writer does not know if he wants to get his GED.
(3) **Cristina:** Not quite! [Short feedback] The writer talks about being a poor student in high school. [Hint] With this in mind, which of the following could be true? Try to press a different answer choice below [Provide another chance].
(4) **Adult Learner:** [Pick the third choice] The author did not learn computer in high school.
(5) **Cristina:** Correct! The writer talks about his or her passion for computers, however the text does not mention learning about them.
(6) **Cristina:** Jordan, what was your answer to this question?
(7) **Jordan (peer agent):** I thought the answer was, the writer knows a lot about computers.

(8) **Cristina:** That is incorrect because the writer does not talk about knowing anything about computers, only liking them. This activity can be really tricky! Even I get tripped up sometimes!
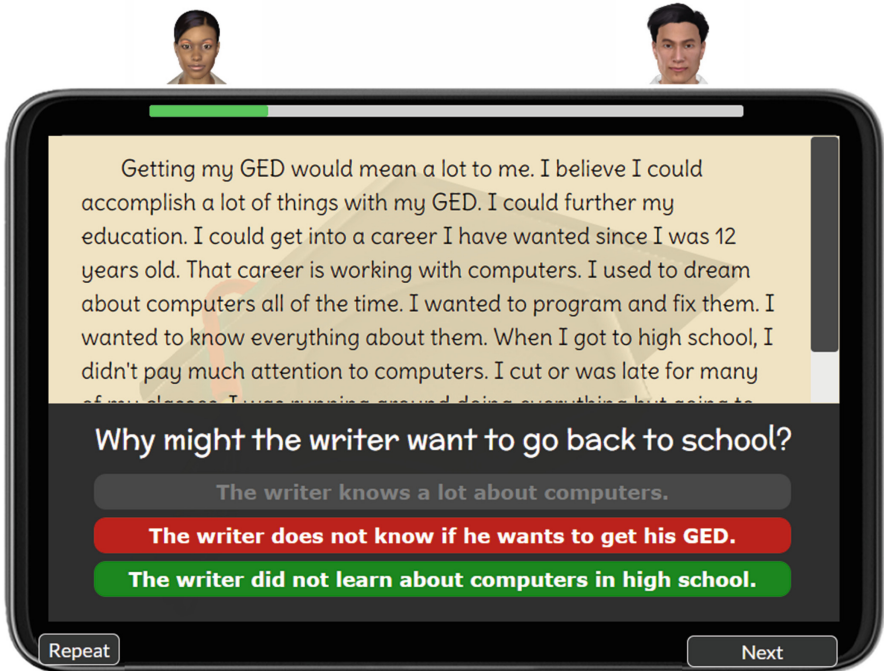

Fig. 2. Screenshot of a AT-ARC lesson.

To sum up, the trialogues were written to be adaptive to the adult learners' knowledge and skills in reading comprehension. However, these trialogues were not all designed in the same lessons.

3.4 Interface

It should be noted that the adult learners have difficulties in writing. So, it is beyond the abilities of most of them to type much verbal information. The best many of them can do is to scroll a webpage, click on multiple choice alternatives, drag and drop information, or toggle on alternatives [18]. In consideration of their limited skills of using computers, AT-ARC does not take the typical form of interaction (by typing answers in a textbox) between computer tutor and human learners. Instead, it tends to rely on point & click interactions, drag & drop functions, multiple choice questions, and limited typing. Therefore, the system does not require much semantic evaluation and regular expression matching of learners' writing contributions to the open-ended main questions, pumps, prompts, and hints.

Several other interface features in AT-ARC were designed to enable self-paced learning. There is a "repeat" button to press whenever the adult learner wants the previous turn of an agent to be repeated. They can press on an option to have text read to them whenever the materials involve a multi-sentence text (but not when a single sentence is presented). They can press the home icon at the bottom whenever they want to start at the beginning of a lesson. In the practice section, after answering a question, the adult learner clicks on the "Next" button to go to the next question. At the end of the lesson, AT-ARC will display an ending page to inform the learners whether they have passed the lesson based on their accuracy on the practice questions. If a learner fails the lesson, AT-ARC suggests they take the lesson again.

4   Final Thoughts

Although much work has been done to improve the adaptivity of AT-ARC, it is far from perfect. Future research can explore the deeper levels of human-computer interaction. For example, AT-ARC incorporates all types of trialogues in each lesson. The computer agents choose the type of trialogues adaptive on adult learners' characteristics, such as their knowledge and skills in reading, motivation, self-efficacy, or even personality. Currently, AT-ARC lessons are organized in a linear form. That is to say, the adult learner cannot jump to an activity (e.g., answering a question, reading a text) by skipping over the previous activities. Another strand of research can focus on breaking a lesson into smaller chunks and making each chunk accessible independently when the adult learner would like to review a specific activity.

References

1. Alamprese, J.A., MacArthur, C.A., Price, C., Knight, D.: Effects of a structured decoding curriculum on adult literacy learners' reading development. J. Res. Educ. Effect. **4**, 154–172 (2011)
2. Carnevale, A.P., Smith, N.: Workplace basics: the skills employees need and employers want. Hum. Resour. Dev. Int. **16**, 491–501 (2013)
3. Driscoll, D.M., Craig, S.D., Gholson, B., Ventura, M., Hu, X., Graesser, A.C.: Vicarious learning: effects of overhearing dialog and monologue-like discourse in a virtual tutoring session. J. Educ. Comput. Res. **29**(4), 431–450 (2003). https://doi.org/10.2190/Q8CM-FH7L-6HJU-DT9W
4. Elish-Piper, L.: Defining adult literacy. In: Guzzetti, B.J. (ed.) Literacy for the New Millennium: Vol. 4. Adult Literacy, pp. 3–16. Praeger, Westport, Connecticut (2007)
5. Graesser, A.C., Forsyth, C.M., Lehman, B.A.: Two heads may be better than one: learning from computer agents in conversational trialogues. Grantee Submission **119**, 1–20 (2017)

6. Graesser, A.C., McNamara, D.S., Cai, Z., Conley, M., Li, H., Pennebaker, J.: Coh-Metrix measures text characteristics at multiple levels of language and discourse. Elem. Sch. J. **115**, 210–229 (2014)
7. Graesser, A.C., et al.: Reading comprehension lessons in AutoTutor for the center for the study of adult literacy. In: Crossley, S.A., McNamara, D.S. (eds.) Adaptive Educational Technologies for Literacy Instruction, pp. 288–293. Taylor & Francis Routledge, New York (2016)
8. Graesser, A.C., Cai, Z., Morgan, B., Wang, L.: Assessment with computer agents that engage in conversational dialogues and trialogues with learners. Comput. Hum. Behav. **76**, 607–616 (2017)
9. Graesser, A.C., Conley, M.W., Olney, A.: Intelligent tutoring systems. In: APA Educational Psychology Handbook, Vol. 3: Application to Learning and Teaching, pp. 451–473 (2012)
10. Graesser, A.C., McNamara, D.S.: Computational analyses of multilevel discourse comprehension. Top. Cogn. Sci. **3**, 371–398 (2011)
11. Meyer, B.F., Wijekumar, K., Middlemiss, W., Higley, K., Lei, P., Meier, C., et al.: Web-based tutoring of the structure strategy with or without elaborated feedback or choice for fifth- and seventh-grade readers. Read. Res. Q. **45**(1), 62–92 (2010)
12. Miller, B., Esposito, L., McCardle, P.: A public health approach to improving the lives of adult learners: Introduction to the special issue on adult literacy interventions. J. Res. Educ. Effect. **4**, 87–100 (2011)
13. National Research Council [NRC]. Improving adult literacy instruction: options for practice and research. The National Academies Press, Washington (2011)
14. Newnan, A.: Learning for Life: The Opportunity for Technology to Transform Adult Education (2015). http://tytonpartners.com/library/learning-for-life-the-opportunity-for-technology-to-transform-adult-education/
15. Nye, B.D., Graesser, A.C., Hu, X.: AutoTutor and family: a review of 17 years of natural language tutoring. Int. J. Artif. Intell. Educ. **24**(4), 427–469 (2014)
16. OECD: Time for the U.S. to Reskill?: What the Survey of Adult Skills Says, OECD Skills Studies, OECD Publishing (2013). https://doi.org/10.1787/9789264204904-en
17. OECD: Adults, Computers and Problem Solving: What's the Problem? OECD Publishing (2015). https://doi.org/10.1787/9789264236844-en
18. Olney, A.M., Bakhtiari, D., Greenberg, D., Graesser A.: Assessing computer literacy of adults with low literacy skills. In: Hu, X., Barnes, T., Hershkovitz, A., Paquette, L. (eds.) Proceedings of the 10th International Conference on Educational Data Mining, pp. 128–134. International Educational Data Mining Society, Wuhan (2017)
19. Perfetti, C.: Reading ability: Lexical quality to comprehension. Sci. Stud. Read. **11**(4), 357–383 (2007)
20. Rasu, R.S., Bawa, W.A., Suminski, R., Snella, K., Warady, B.: Health literacy impact on national healthcare utilization and expenditure. Int. J. Health Policy Manag. **4**(11), 747 (2015)
21. Sabatini, J.P., Shore, J., Holtzman, S., Scarborough, H.S.: Relative effectiveness of reading intervention programs for adults with low literacy. J. Res. Educ. Effect. **4**, 118–133 (2011)
22. Wass, R., Golding, C.: Sharpening a tool for teaching: the zone of proximal development. Teach. High. Educ. **19**(6), 671–684 (2014)
23. Zwaan, R.A., Radvansky, G.A.: Situation models in language comprehension and memory. Psychol. Bull. **123**, 162–185 (1998)