

**Conversational Agents Can Help Humans Identify Flaws in the Science
Reported in Digital Media**

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Conversational Agents Can Help Humans Identify Flaws in the Science Reported in Digital Media

It is widely believed that information in print, spoken, and digital media is replete with inaccuracies, especially now that there is less editing of content in most media outlets. Inaccurate information may range from a single sentence that conveys a fact or claim to lengthy discourse that incorporates a deeply flawed mental model. Sometimes there are explicit contradictions within a text or between texts. At other times the contradictions require inferences and careful scrutiny with respect to prior knowledge. This is impossible or difficult for readers who have low knowledge about the subject matter. They cannot identify false information or resolve contradictions without conceptual knowledge about the domain. Individuals respond in a variety of ways to these inaccuracies. The most gullible readers accept virtually all content as true and miss most contradictions. The most skeptical readers question the veracity of most content and are on the lookout for contradictions. Most individuals undoubtedly fall somewhere in between these two extremes on the gullible-skeptical continuum.

Most of the chapters in this volume investigate how individuals by themselves process and respond to the inaccurate information. Does the reader notice such information? Do they ask questions about it? Do they discard it? Do they abandon the information source altogether? Do they read a different information source to check it out? Do they challenge the author? This chapter stretches beyond individual responses to inaccurate information. Our research incorporates conversational computer agents (called *agents* for short) that interact with the human while the human comprehends information sources. The agents hold conversations with the human that scrutinizes the reliability, accuracy, validity, and completeness of the content expressed in information sources. The hope is that these social interactions between humans and

agents will help the human learn strategies of identifying inaccuracies and to automatize such skills. Ideally the human will shift a bit from the gullible to the skeptical end of the continuum and will possibly converge on a sweet spot of intelligent scrutiny.

The chapter discusses two classes of agent-based computer systems. The next section describes systems that have a single agent interacting with a human during the course of reading science content from the web (such as *SEEK Web Tutor*) or evaluating whether a scientific experiment has an ethical problem (such as *HURA Advisor*). The subsequent section describes a system called *Operation ARIES!* that has two or more agents interacting with a human while evaluating whether a science news report in the media does or does not have flawed scientific methodology. Sometimes two agents contradict each other; sometimes two agents agree on a false claim. We examine how the human learner responds (both cognitively and emotionally) to the agents as they express inaccurate information. The materials in all of these studies involve STEM (Science, Technology, Engineering, Mathematics) content.

Single Agents Interacting with the Human

Learning environments with pedagogical agents have been developed to serve as substitutes for humans who range in expertise from peers to subject matter experts with pedagogical strategies. Agents can guide the interaction with the learner, instruct the adult learner what to do, and interact with other agents to model ideal behavior, strategies, reflections, and social interactions (Baylor & Kim, 2005; Graesser, Dufty, & Jeon, 2008; Millis et al., 2011). Some agents generate speech, gestures, body movements, and facial expressions in ways similar to people, as exemplified by *Betty's Brain* (Biswas, Jeong, Kinnebrew, Sulcer, & Roscoe, 2010), *Tactical Language and Culture System* (Johnson & Valente, 2008), *iSTART* (McNamara, Boonthum, Levinstein, & Millis, 2007; McNamara, O'Reilly, Best, & Ozuru, 2006), *Crystal Island* (Rowe,

Shores, Mott, & Lester, 2010), and *My Science Tutor* (Ward et al., 2011). Systems like *AutoTutor* and *Why-Atlas* can interpret the natural language of the human that is generated in spoken or typed channels and can respond adaptively to what the student expresses (Graesser et al., 2012; D’Mello, Dowell, & Graesser, 2011; VanLehn et al., 2007). These agent-based systems have frequently demonstrated value in improving students’ learning and motivation (Graesser, Conley, & Olney, 2012; VanLehn, 2011) but it is beyond the scope of this chapter to review the broad body of research on agents in learning environments.

This section describes two learning environments with single agents that assist the student in handling inaccuracies and problematic content in STEM topics. *SEEK Web Tutor* (Graesser et al., 2007) was designed to directly teach students how to take a critical stance when evaluating science content on the Internet. *HURA Advisor* (Hu & Graesser, 2004) was designed to train students on the fundamentals of research ethics and to identify ethical flaws in scientific research. After discussing the successes and failures of these two systems, we speculate on how more powerful systems can be designed to help students acquire intelligent scrutiny.

SEEK (Source, Evidence, Explanation, and Knowledge) Web Tutor

Critical thinking about science requires learners to actively evaluate the truth and relevance of information, the quality of information sources, the plausibility of causal systems, and the implications of evidence (Braasch et al., 2009; Bråten, Strømsø, & Britt, 2009; Britt & Aglinskias, 2002; Goldman et al., 2012; Halpern, 2003; Rouet, 2006; Wiley et al., 2009). A deep understanding is needed to construct causal reasoning, integration of the components in complex systems, and logical justifications of claims. This is very difficult to achieve without sufficient prior knowledge about a domain and reasoning skills (Kendeou & Van den Broek, 2007). However, a major start is for the student to acquire a thinking strategy with a *critical stance* – essentially the

skeptic. An individual with a critical stance considers the possibility that there may be problems with the truth, relevance, or quality of the information that is received. A critical stance toward scientific information is especially important in the digital age.

SEEK Web Tutor (Graesser, Wiley et al., 2007) was designed to improve college students' critical stance while they search web pages on the topic of plate tectonics. Some of the web sites were reliable information sources on the topic, written by professionals in the National Aeronautics and Space Administration, the Public Broadcasting Service, and Scientific American. Others were erroneous accounts of earthquakes and volcanoes that appealed to the stars, the moon, and oil drilling. The student's goal in the experiments was to search the web for the purpose of writing an essay on what caused the eruption of the Mt. St. Helens volcano in 1980.

SEEK Web Tutor took a direct approach to training students on critical stance by implementing three facilities with different instruction methods. The first was a *Hint* button on the Google search engine page that contained suggestions on how a student can strategically search and read a set of web sites. This page was a mock Google page with titles and URL's for reliable and unreliable web sites, which could be accessed and explored if the student so desired. When a student clicked the Hint button, spoken messages gave reminders of the goal of the task (i.e., writing an essay on the causes of the Mt. St. Helens volcano eruption in the state of Washington) and suggestions on what to do next (i.e., reading web sites with reliable information). The agent in one version of the SEEK Tutor had a talking head, but the final version had "voice only" facility because there was a worry that the visual animation of the head would create a distraction from the web material to be learned. Research has subsequently revealed that such worries are unwarranted if the talking heads are designed appropriately (Graesser, Moreno et al., 2003; Louwerse, Graesser,

McNamara, & Lu, 2009). Viewers of learning technologies in the modern world are quite adept at attending to conversational agents at appropriate moments.

It should be noted that the spoken messages of this first facility only were presented if the student decided to click the Hint button. In reflection, this was an unfortunate design decision because students rarely ask for help (Graesser, McNamara, & VanLehn, 2005; Graesser & Person, 1994) unless they are gaming the system to avoid learning, a condition that does not apply here.

The second computer facility was a pop-up *Rating and Justification* that asked students to evaluate the expected reliability of the information in a site. Figure 1 shows an example web page and the associated pop-up Rating and Justification. This facility deterministically appeared after the students first viewed a particular website for 20 seconds. The student rated the reliability of the information and typed in a verbal justification of the rating.

INSERT FIGURE 1 ABOUT HERE

The third computer facility consisted of a pop-up *Journal* that had five questions about the reliability of the site that the learner just visited. These questions were designed to address some of the core aspects of critical stance: *Who authored this site? How trustworthy is it? What explanation do they offer for the cause of volcanic eruptions? What support do they offer for this explanation? Is this information useful to you, and if so, how will you use it?* Each of the questions had a Hint button that could be pressed to receive spoken hints on answering each question. The pop-up Journal was launched whenever the learner left one of the web sites. It forced the learner to think about each of the five core aspects of critical stance. They not only gave a rating for each question but also typed in a verbal justification for each rating.

The three computer facilities were expected to weather in a habit of mind with a critical stance by direct didactic training and application of the principles to the exemplar web sites. We conducted some experiments to test the effectiveness of this approach (Graesser, Wiley et al., 2007). College students explored the web sites for approximately 1 hour with the goal of writing an essay on the causes of the eruption of Mt. St. Helens. Participants were randomly assigned to either the *SEEK Web Tutor* condition or to a *Navigation* condition that had no training on critical stance. The 1-hour training with the Tutor was expected to enhance a critical stance, as assessed by over a dozen measures, including an essay on the causes of a volcano. Unfortunately, we were quite mistaken. An hour of intense training on critical stance had very little impact on college students. SEEK Web Tutor did not improve learners' ability to detect reliable versus unreliable information sources during training, the amount of study time they allocated to reliable versus unreliable sites, their judgments of the truth/falsity of 30 statements about plate tectonics after the training was completed, and the articulation of core ideas about plate tectonics in the essays. After assessing over a dozen measures, there was only one measure that showed a benefit of the SEEK Web Tutor over the navigation control. Namely, we found that students had more expressions in the essay with language about causal explanations (such as "cause" and "explanation") compared to navigation controls. We concluded that SEEK Web Tutor did influence the causal language in their essays, but had no noticeable influence on critical stance during the learning processes, on articulation of critical stance principles, on detection of truth versus falsity, and on the acquisition of a deep mental model of science.

There are of course many reasons why the direct approach to instruction was unimpressive. One explanation is that there needs to be much more training. Perhaps dozens of hours of SEEK Web Tutor on multiple topics and problems are needed before benefits are realized for deep science

learning and the application of a critical stance. Another explanation is that there needs to be a more adaptive, intelligent, tailored interaction with the student in the context of specific cases before more noticeable improvements will occur. Expertise does not simply fall out from time on task, but rather requires expert tutoring on critical constructs and milestones in the context of specific experiences. This raises the bar for both computer and human learning environments.

Human Use Regulatory Affairs Advisor (HURA Advisor)

HURA Advisor (HURAA) was a comprehensive learning environment on the web that helped adults learn the policies on the ethical use of human subjects in research. The system had a full suite of facilities: (1) didactic lessons that resemble PowerPoint lectures, (2) a technical document repository, (3) hypertext at a deep hierarchically nested grain size, (4) multimedia (including an engaging video), (5) lessons with concrete scenarios to assess case-based reasoning on research ethics, (6) query-based information retrieval, and (7) an animated agent that served as a navigational guide (Hu & Graesser, 2004).

The agent navigational guide provided coherence on the entire learning experience. Figure 2 shows the layout of the interface of the learning environment. The animated conversational agent of HURAA appeared in the upper left of the web page and served as a navigational guide to the student. The agent suggested what to do next and answered student questions that matched entries in a frequently asked question database. Below the agent was a column with labels for the major learning modules that spanned a broad array of learning technologies (1-6 above). An intelligent agent could direct the student on which of these facilities to use, but the system we ended up designing did not have that adaptive intelligence. Perhaps interactivity, adaptation, and intelligence of the system matters, but we could not assess that with this instantiation of HURAA.

INSERT FIGURE 2 ABOUT HERE

One component that did have adaptive intelligence is the case study module. Students were presented a series of cases and asked to identify ethical flaws. For example, the experiment described in Figure 2 may have violated one or more of the seven principles: Social or scientific value, scientific validity, fair subject selection, favorable risk-benefit ratio, independent review, informed consent, and respect for enrolled subjects. The participants rated the extent to which each case had problems with each of the 7 dimensions. The system then gave feedback on their ratings and presented what a panel of experts would say. To be adaptive, the selection of case N was expected to be sensitive to performance on the prior case, such that the new case should have unresolved problems of the past.

HURAA was evaluated in experiments that contrasted it with conventional computer-based instruction containing the same content that controlled for information equivalence as best it could. Such controls on content between interventions are equally important as time on task; time on task is irrelevant without an information theoretical analysis of content. The results of Hu and Graesser (2004) were both positive and negative after collecting dozens measures of retention, reasoning, and inquiry. Memory for core concepts was enhanced by HURAA compared to the conventional web software, with effect sizes averaging 0.78. HURAA's answers to students' questions in the information retrieval facilities were impressive, with 95% of the answers being judged as relevant by the learner and 50% judged as being informative. Unfortunately, however, HURAA had no significant increment for several measures compared with the control condition: case-based reasoning, the speed of accessing information when trainees were given difficult questions that required information search, and perceptions of the system with respect to interest, enjoyment, amount learned, and ease of learning. Interestingly,

no significant differences occurred in any of the measures we collected when we conducted an experiment that compared the agent's messages being presented in different media, i.e., the full animated conversational agent, text-only, voice-only, and text+voice (Graesser, Ventura, Jackson, Mueller, Hu, & Person, 2003). Simply concluded, it is the content of what the agent says in the conversation that matters rather than the medium of message delivery.

One of the painful lessons from our research on single agents is that there are very limited outcomes of single agents on an ensemble of training methods in a 1-hour period. There needs to be much more extensive training and diversity of experiences to compete with a 20 year old that has had 20 years of life's experiences.

Multiple Agents Interacting with the Human

The incremental value of multiple agents is that the human can see how others respond and adjust knowledge accordingly. The social world opens up a large array of possibilities in acquiring a critical stance. A student can learn vicariously by observing one agent interacting with another agent and exhibiting strategies with a critical stance. Two agents can disagree, contradict each other, and hold an argument, periodically turning to the student to solicit the student's perspective. The agents can correct each other or the student when false information is expressed. And vice versa, the student can correct the agents when they express false information or faulty reasoning. This section describes some studies with agents in learning environments that have false information, faulty reasoning, and various barriers to comprehension. The studies involve two agents interacting with a human student in what is called a *dialog*.

Trialogs with Contradictions in Operation ARIES and Operation ARA

The dialog studies involved two agents and a student critiquing case studies of scientific research with respect to scientific methodology. The design of the case studies and dialog

critiques were inspired by a serious game called *Operation ARIES!* (Forsyth et al., 2013; Millis et al., 2011), which was subsequently commercialized by Pearson Education as *Operation ARA* (Halpern et al., 2012). Players learn how to critically evaluate research they encounter in various media, such as the Web, TV, magazines and newspapers. ARIES is an acronym for **A**cquiring **R**esearch **I**nvestigative and **E**valuative **S**kills. The game teaches how to critically evaluate aspects of scientific investigations (e.g., the need for control groups, adequate samples of observations, operational definitions, etc.) and how to ask appropriate questions in order to uncover problems with design or interpretation. Scientific inquiry is crucial because it comprises the necessary steps of “science as process,” the steps that scientists follow in establishing and critiquing causal claims. Figure 3 shows the interface of ARIES, showing multiple agents, a case to be increased and other components of the learning environment.

INSERT FIGURE 3 ABOUT HERE

It could be argued that scientific reasoning and inquiry are core skills of citizens in the information age. The public is constantly being exposed to causal claims made by scientists, advertisers, coworkers, friends, and the press via a variety of media (blogs, TV, Web, print, word of mouth). Of course, some of the claims have relatively solid scientific evidence for support, whereas others do not. In some cases, the research is well executed, but the interpretation or conclusion drawn by the press is inappropriate. For example, consider a headline that makes a causal claim that “wine lowers heart attack risk in women,” based on a correlational design which does not support a cause-effect interpretation. In other cases, a claim is unfounded because the design of the study itself is flawed or nonexistent. Consider a TV news report that concludes that teenagers are too immature to drive, with a film depicting irresponsible teens and a statistic that reports how many automobile accidents they had in a given year. There is no comparison

group, operational definition, and systematic collection of data. An informed viewer should be able to identify the problems with such a flimsy news report. There can be costly consequences to the misinformation. According to the U.S. National Institute of Health (NIH), approximately four million U.S. adults and one million U.S. children used homeopathy and other alternative medicines in 2006, even though there is little or no benefit of these medicines beyond placebo effects.

We have conducted a series of studies that plant false information and contradictions in the trialogs as case studies are critiqued (D'Mello, Lehman, Pekrun, & Graesser, in press; Lehman, D'Mello, & Graesser, 2012). A 3-way trialog conversation transpired between the human student, a tutor agent, and a student agent. The tutor-agent was an expert on scientific inquiry whereas the student-agent was a peer of the human learner. A series of cases were presented to the student that described experiments that may have had a number of flaws with respect to scientific methodology. For example, one case study described a new pill that purportedly helps people lose weight, but the sample size was small and there was no control group. The goal of the participants in the trialog was to identify the flaws and express them in natural language.

Lehman et al. (2012) attempted to plant cognitive disequilibrium by manipulating whether or not the tutor agent and the student agent contradicted each other during the trialog and expressed points that are incorrect. Each case study had a description of a research study that was to be critiqued during the trialogs. That is, the tutor agent and student agent engaged in a short exchange about (a) whether there was a flaw in the study and (b) if there *was* a flaw, which part of the study was flawed. The tutor agent expressed a correct assertion and the student agent agreed with the tutor in the *True-True* control condition. In the *True-False* condition, the tutor

expressed a correct assertion but the student agent disagreed by expressing an incorrect assertion. In the *False-True* condition it was the student agent who provided the correct assertion and the tutor agent who disagreed. In the *False-False* condition, the tutor agent provided an incorrect assertion and the student agent agreed.

The human student was asked to intervene after particular points of possible contradiction in the conversation. For example, the agents turned to the human and asked “Do you agree with Chris (student agent) that the control group in this study was flawed?” The human’s response was coded as correct if he/she agreed with the agent who had made the correct assertion about the flaw of the study. If the human experienced uncertainty and was confused, this should be reflected in the incorrectness and/or uncertainty of the human’s answer. This uncertainty would ideally stimulate thinking and learning.

The data indeed confirmed that the contradictions and false information had an impact on the humans’ answers to these Yes-No questions immediately following a contradiction. The proportion of correct student responses showed the following order: True-True > True-False > False-True > False-False conditions. These findings indicated that learners were occasionally confused when both agents agreed and were correct (True-True, no contradiction), became more confused when there was a contradiction between the two agents (True-False or False-True), and were either confused or simply accepted the incorrect information when the agents incorrectly agreed (False-False). Confusion would be best operationally defined as occurring if both (a) the student manifests uncertainty/incorrectness in their decisions when asked by the agents and (b) the student either reports being confused or the computer automatically detects confusion (through technologies that track discourse interaction, facial expressions, and body posture that

are beyond the scope of this article to discuss; D’Mello & Graesser, 2010; Graesser & D’Mello, 2012).

The ARIES inspired dialog studies also showed that contradictions, confusion, and uncertainty caused more learning at deeper levels of mastery, as reflected in a delayed test on scientific reasoning. The results indicated that contradictions in the False-True condition produced higher performance on multiple choice questions that tapped deeper levels of comprehension than performance in the True-True condition. Identification of flaws on far-transfer case studies in a delayed test also showed significant benefits over the True-True condition without contradictions. Thus, the results indicated that the most uncertainty occurred when the tutor agent made false claims that the student agent disagreed with, that the contradictions stimulated thought and reasoning at deeper levels, and that scores on a delayed posttest were improved by this experience. These data suggest that there may be a causal relationship between contradictions (and the associated cognitive disequilibrium) and deep learning, with confusion playing either a mediating, moderating, or causal role in the process. The results and interpretation are compatible with other researchers who have emphasized the role of confusion as a necessary early step in conceptual change (Posner, Strike, Hewson, & Gertzog, 1982) and the role of cognitive conflict as crucial for deeper learning (van den Broek & Kendeou, 2008). It is indeed compatible with Piagetian theory of intellectual development (Piaget, 2008).

It is illuminating that the False-False condition did not engender much uncertainty and confusion. The students pretty much accepted what the tutor and student agents expressed when they agreed, even if the claims were false. An alternative possibility could have been that the claims of the two agents would clash with the reasoning and belief system of the human.

However, that rarely occurred among the college students who participated in this study. This result is compatible with models that predict that it takes a large amount of world knowledge before a student can detect what they don't know (knowledge gaps) (Miyake & Norman, 1979), false information (Rapp, 2008), and contradictory information (Baker, 1985; O'Brien, Rizzella, Albrecht, & Halleran, 1998). A strategic, skeptical, critical stance is the only hope for the human when the person is not fortified with sufficient subject matter knowledge.

There was a need for the two agents to directly contradict each other in a conversation before the humans experienced an appreciable amount of uncertainty and confusion. We suspect that the contradiction would need to be contiguous in time before the contradiction would be detected. That is, the contradiction is likely to be missed if one agent makes a claim and then another agent makes a contradictory claim 10 minutes later. This is compatible with research in text comprehension that has shown that the contradictory claims must be co-present in working memory before they get noticed (Baker, 1985; Otero & Kintsch, 1992), unless there is a high amount of world knowledge. It is also compatible with the observation that it is difficult for many students to integrate information from multiple texts and spot contradictions (Bråten et al., 2009; Britt & Aglinskias, 2002; Goldman et al., 2012; Rouet, 2006) unless there is a high amount of world knowledge. A strategic attempt to integrate information from multiple texts would be needed to draw such connections unless the person is fortified with sufficient subject matter knowledge (Goldman et al., 2012; Graesser et al., 2007; Wiley et al., 2009).

Our research on dialogues with agent contradictions has illustrated the benefits of learning at deep levels when putting students in cognitive disequilibrium. The result is compatible with our research on the AutoTutor agent that helps students learn by holding a conversation in natural language and that tracks their moment-by-moment emotions (i.e., cognitive-affective

mixtures) during the learning process (D'Mello & Graesser, 2012; Graesser & D'Mello, 2012). The common emotions during learning are boredom, engagement/flow, frustration, confusion, delight, and surprise in a wide range of learning environments (Baker, D'Mello, Rodrigo, & Graesser, 2010). The learning-centered emotion that best predicts learning at deeper levels is confusion, a cognitive-affective state associated with thought and deliberation (Craig et al., 2004; D'Mello & Graesser, 2012; D'Mello, Lehman, Pekrun, & Graesser, in press; Graesser & D'Mello, 2012).

We have been investigating a cognitive disequilibrium framework that integrates a number of psychological processes: confusion (and other learning-centered emotions), question asking (inquiry), deliberative thought, and deeper learning. Cognitive disequilibrium is a state that occurs when people face obstacles to goals, interruptions, contradictions, incongruities, anomalies, impasses, uncertainty, and salient contrasts (Barth & Funke, 2010; D'Mello & Graesser, 2012; Festinger, 1957; Graesser, Lu, Olde, Cooper-Pye, & Witten, 2005; Mandler, 1999; Piaget, 1952; Schwartz & Bransford, 1998). Initially the person experiences various emotions when beset with cognitive disequilibrium, but notably confusion, surprise, or curiosity (D'Mello & Graesser, 2012; D'Mello et al., in press; Graesser & D'Mello, 2012; Lehman, D'Mello & Graesser, 2012). This elicits question asking and other forms of inquiry (Graesser & McMahan, 1993; Graesser, Lu et al., 2005; Otero & Graesser, 2001), such as social interaction, physical exploration of the environment, or the monitoring of focal attention. The person engages in problem solving, reasoning, and other thoughtful cognitive activities in an attempt to resolve the impasse and restore cognitive equilibrium. The consequence is deeper learning.

There are of course individual differences in the handling of cognitive disequilibrium. Relevant traits tap constructs of motivation, self-concept, and goal orientations (Deci & Ryan,

2002; Dweck, 2002; Pekrun, 2006; Meyer & Turner, 2006). Responses to cognitive disequilibrium depend on the learners' appraisal or reappraisal of their own abilities, their goals, the event that triggered the disequilibrium, and the context (Ortony, Clore, & Collins, 1988). For example, some students enjoy high levels of disequilibrium, confusion, and frustration over a lengthy time span when playing games; other students are not comfortable with the disequilibrium even in game environments. Some students give up and conclude they are not good at the subject matter or skill, whereas others see it as a challenge to be conquered with an investment of effort (Dweck, 2002).

There are other systems with trialogs and multiple agents that train students on cognitive and metacognitive skills that have relevance to the detection and handling of incorrect information. Four of these systems are briefly described next.

MetaTutor training on Self-Regulated Learning

MetaTutor trains students on 13 strategies that are theoretically important for self-regulated learning (Azevedo, Moos, Johnson, & Chauncey, 2010). The process of self-regulated learning (SRL) theoretically involves the learners' constructing a plan, monitoring metacognitive activities, implementing learning strategies, and reflecting on their progress and achievements. The MetaTutor system has a main agent (Gavin) that coordinates the overall learning environment and three satellite agents that handle three phases of SRL: Planning, monitoring, and applying learning strategies. Each of these phases can be decomposed further, under the guidance of the assigned conversational agent. For example, metacognitive monitoring can be decomposed into judgments of learning, feeling of knowing, content evaluation, monitoring the adequacy of a strategy, and monitoring progress towards goals. Examples of learning strategies include searching for relevant information in a goal-directed fashion, taking notes, drawing

tables or diagrams, re-reading, elaborating the material, making inferences, and coordinating information sources (text and diagrams). Each of these metacognitive and SRL skills have associated measures that are based on the student's actions, decisions, ratings, and verbal input. The frequency and accuracy of each measured skill is collected throughout the tutoring session and hopefully increases as a function of direct training. The MetaTutor training would be expected to improve a person's detection of incorrect information through the monitoring component and also the strategies that compare information in different documents and media.

Teachable Agents with Betty's Brain

Betty's Brain (Biswas et al, 2010; Schwartz et al., 2009) requires the human student to teach an agent named Betty about causal relationships in a biological system that is depicted in a conceptual graph. Betty has to get the conceptual graph correct in order to pass a multiple-choice test. When she fails, the human interacts with Betty to improve her conceptual graph and thereby improve her scores. Another mentor agent guides this interaction through comments, hints, and suggestions to the human learner. The dialogues utilize learning-through-teaching and also precise accountability on the quality of the teacher's actions. The human student teaches the student agent, with the tutor agent periodically entering the conversation to guide a productive interaction. It takes a sufficient amount of knowledge to produce the content to teach the student agent. Betty will fail the test if the teacher does not set up the correct graph so incorrect links are detected.

iDRIVE (Instruction with Deep-level Reasoning questions In Vicarious Environments)

iDRIVE has two agents train students to learn science content by modeling deep reasoning questions in question-answer dialogues (Craig, Sullins, Witherspoon, & Gholson, 2006; Gholson et al., 2009). A student agent asks a series of deep questions about the science

content and the teacher agent immediately answers each question. Approximately 30 good questions are asked (by the student agent) and answered (by the tutor agent) per hour in this learning environment so high quality inquiry is weathered into the students' thinking habits. There is evidence that learning gains are higher and students ask better questions for those students who have the mindset of asking deep questions (*why, how, what-if, what-if-not*) that tap causal structures, complex systems, and logical justifications (Graesser & Olde, 2003). When students are trained how to ask good questions, the frequency of good questions increases and their text comprehension improves (Gholson & Craig, 2006; Rosenshine, Meister, & Chapman, 1996). We expect that sophisticated inquiry skills will help them detect misinformation and also to compare different information sources when contradictions arise.

iSTART (Interactive Strategy Trainer for Active Reading and Thinking)

This strategy trainer helps students become better readers by monitoring comprehension at deep levels and constructing self-explanations of the text (McNamara, O'Reilly, Rowe, Boonthum, & Levinstein, 2007). The construction of self-explanations during reading is known to facilitate deep comprehension (Chi et al., 1989), particularly when there is some context-sensitive feedback on the explanations that get produced (McNamara, O'Reilly, Best, & Ozuru, 2006). The iSTART interventions focus on five reading strategies that are designed to enhance self-explanations: *monitoring comprehension* (i.e., recognizing comprehension failures and the need for remedial strategies), *paraphrasing* explicit text, making *bridging inferences* between the current sentence and prior text, making *predictions* about the subsequent text, and *elaborating* the text with links to what the reader already knows. The accuracy of applying these metacognitive skills is measured and tracked throughout the tutorial session.

Groups of agents scaffold these strategies in three phases of training. In an *Introduction Module*, a trio of agents (an instructor and two students) collaboratively describes self-explanation strategies with each other. In a *Demonstration Module*, two agents demonstrate the use of self-explanation in the context of a science passage and then the student identifies the strategies being used. A measure of metacognitive skill is the accuracy of the students' identifying the correct strategy exhibited by the student agent. In a final *Practice* phase, an agent coaches and provides feedback to the student one-to-one while the student practices self-explanation reading strategies. That is, for particular sentences in a text, the agent reads the sentence and asks the student to self-explain it by typing a self-explanation. The iSTART system then attempts to interpret the student's contributions, gives feedback, and asks the trainee to modify unsatisfactory self-explanations (McNamara, Boonthum, Levinstein, & Millis, 2007). Improved skills with comprehension monitoring and self-explanation would be expected to help students detect misinformation and explain how to resolve discrepancies among claims and information sources.

Closing Comments

This chapter has described some learning environments with agents that are designed to help students detect misinformation and incompatibilities among different information sources. Many students are gullible and accept the information presented in different sources so they need to be trained to have a critical stance. The skeptical students are more vigilant in detecting false claims, faulty reasoning, and contradictions among sources. It is of course healthy to adopt a skeptical stance when comprehending some genres of documents, such as editorials, blogs, web sites, and tweets. However, a critical stance is also needed for virtually all documents in the

information age, including those in print, particularly as editors are less likely to scrutinize the content.

The learning environments with agents can help humans acquire a critical stance that helps inoculate them from misinformation. Systems with agents train students to evaluate the quality of web sites (SEEK Web Tutor), identify problematic ethics in research studies (HURA Advisor), identify science news articles with faulty research methods (Operation ARIES and ARA), acquire metacognitive skills for self-regulated learning (MetaTutor), identify gaps and faulty links in knowledge representations (Betty's Brain), ask deep questions (iDRIVE), and monitor comprehension and self-explain during reading (iSTART). Some of these trainers have a single computer agent whereas others have 2 or more agents that take on different roles. All of these trainers are intelligent and flexibly interact with students in ways that attempt to adapt to individual needs of the learners. All of them have been tested on humans and have shown improvements in metacognitive skills, reasoning, and/or deeper knowledge of the subject matter – all of which allegedly help the learner detect misinformation.

The agents are needed to train most students on how to handle misinformation because their habits of mind are not reliably geared to spot information pollution. According to the cognitive disequilibrium model discussed in this chapter, a number of processes would occur when a person receives information that either contradicts another claim or clashes with what a person knows: (1) Detection of the misinformation neurally, as manifested by the N400 (Kutas & Federmeier, 2000), (2) surprise, curiosity, or another cognitive-affective process, (3) muscular tension, (4) eye movements for exploration, (5) confusion, (6) inquiry and question asking, (7) reasoning and problem solving, (8) explicit acknowledgement of the misinformation, (9) physical actions, and (10) social interactions for help. We are uncertain about the specific

ordering of these processes, which are no doubt interactive, but the higher numbers tend to be later in the psychological timeline. Nevertheless, we are certain that agents or other forms of training are needed to help students intelligently execute the processes associated with the higher numbers.

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Figure 1. Web page with Pop-Up Rating and Justification for the SEEK Web Tutor.

The screenshot shows a web browser window titled 'Form1' displaying an article from PBS Online and Thirteen WNET New York. The article is titled 'SAVAGE EARTH' and 'OUT OF THE INFERNO: VOLCANOES'. The main heading is 'Mountains of Fire' by Kathy Svitil. A pop-up window titled 'Rate this site' is overlaid on the article, asking the user to rate the site on a scale of 1 to 6 (where 6 is most reliable) and to provide reasons for the rating. The user has entered a rating of 5 and the reason 'I think this site is fairly reliable because it seems more factual based'. The 'Submit' button is visible at the bottom of the pop-up.

Rate this site

Please rate this site on a scale of 1 to 6. (Where 6 is most reliable):

Please give your reasons for this rating?

Mountains of Fire
by Kathy Svitil

No geological phenomenon assails our senses enough, and you can hear the explosion, see ground tremble, taste the ash in your mouth grade school kids," says Chris Nye, a volcano Anchorage. "And scientifically, volcanoes are about the interior of the planet, down to 60 miles the planets, on a human time scale. Mostly thousands or millions of years."

All volcanoes are born when hot magma rises to the surface, infiltrates a weak spot or opening in the Earth's outer crust, and erupts through. Most of the 600-plus active volcanoes on Earth are associated with the boundaries of the tectonic plates, the seven great plates that carry the oceans and continents. Volcanoes tend to cluster along mountain belts. The folding and fracturing of plates that creates mountains, breaks up solid rock and creates channels for magma.

Volcanoes are especially common in mountainous regions of subduction zones, places where one plate dips beneath another. As the plate dives into the mantle -- the layer of hot, flexible rock on which the plates glide -- it gradually is heated. That releases fluids which heat the overlying rock, producing blobs of molten rock that rise to the surface. The molten rock -- or magma -- collects in weak patches of crust, in structures called magma chambers. If the pressure in the magma chamber builds high enough, the magma will erupt. A volcano is born. [Page 2](#)

Article: [Mountains of Fire](#) | [Sidebar One: Volcanoes of North America](#) | [Sidebar Two: Montserrat](#) | [Sidebar Three: Other Planets](#) | [PBS Online](#) | [Thirteen Online](#)

Figure 2. Interface of the HURA Advisor.

The screenshot displays the HURA Advisor interface within a web browser window. The interface is set against a dark blue background. At the top, there are navigation buttons labeled "BACK" and "NEXT". Below these, a dark blue box contains the following text:

MODULE Lessons
 LESSON Lesson 3
 STEP 1 Read the case study

On the left side, there is a 3D avatar of a man in a white lab coat and blue tie. Below the avatar is a vertical navigation menu with the following items:

- HISTORICAL OVERVIEW
- LESSONS
- EXPLORE ISSUES
- EXPLORE CASES
- DECISION MAKING
- QUERY DOCUMENTS
- Glossary
- Archives & Links
- Module Descriptions
- Bibliography
- System Requirements
- Help
- Log Out

The main content area features a light gray box with the following text:

A ROUTINE FLIGHT TEST WITH AN EXPERIMENTAL HELMET

The US Air Force is developing new helmet-mounted devices. These devices will reduce fighter pilot workload and improve overall effectiveness of A-10 aircraft which operate in close air support of ground forces. The helmet-mounted devices will require the addition of a two-pound battery to the helmet. Current USAF military test pilots will be used in this study.

The subjects for this [research](#) will be selected from military aviators assigned to the Flight Test Wing. It is proposed that volunteers be recruited at an all-hands meeting following an introduction of the experiment by the squadron commander. Because the A-10 aircraft is engaged in aerial combat, only male pilots will be allowed to participate. Since this experiment involves the development of equipment and the use of human subjects is incidental, no IRB review has been requested by the safety officer, nor the [principal investigator](#).

No special documentation has been prepared as part of this [protocol](#) to be provided to the test pilots selected.

At the bottom of the content box, there is a yellow play button icon followed by the text "Test your knowledge".

Below the content box, a dark blue bar contains the text "SEARCH ORIGINAL DOCUMENTS".

At the very bottom of the interface, there are four small logos: a circular seal, the IDA logo, a shield-shaped logo, and a stylized figure logo.

Figure 3. *Interface of Operation ARIES!*

The screenshot shows a web browser window titled "Case Study - Operation ARIES!". The interface is divided into two main sections.

Left Panel (Quiz Interface):

- At the top, there are four profile pictures: Dr. Quinn, Broth, Tracy, and Stephen. Below each name is a score of 0.
- A section titled "You typed" has an empty text input field.
- A section titled "Closest match" has an empty text input field.
- A section titled "Answer" has an empty text input field.
- Below these sections are two buttons: "Press for answer" and "No (more) flaws".
- A text box contains the following text:

Dr. Quinn: OK. Let us start.
Dr. Quinn: This study is about differences in strength that are observed in different primates. Please enter the flaws you find, if any. Press the No Flaw button if you think there is no flaw in the experiment.
- Below the text box is a label "Input flaw, when ready press Enter on keyboard" and a text input field.
- At the bottom left is a button labeled "Big Book of Science" and at the bottom right is a button labeled "Buy List".

Right Panel (Text Article):

- The header features the "Operation ARIES!" logo with the tagline "Defending Science: Defeating Ignorance" and a small cartoon character.
- The title of the article is "Which Is Stronger-A Gorilla Or A Chimp?".
- The first paragraph reads: "Everybody loves going on field trips to the zoo. But field trips to the zoo provide more than just a day off from the classroom for kids. It provides an opportunity to learn about science!"
- The second paragraph reads: "Mrs. Young, a fifth grade teacher in our district, was especially excited to bring her class to the zoo this year because she knew that they were going to get to see a zoologist test the strength of the different primates. As Mrs. Young observed, 'Not only is it interesting for the students to get to see all the different animals, but they are going to be learning about how strong the different animals are, as well.'"
- The third paragraph reads: "The main research goal for the zoologist was to compare the strength of chimpanzees and gorillas with the expectation that there would be a difference. First, she trained 4 chimps and 4 gorillas to lift up different sized, light-weight objects by rewarding them with food. She then tested the animals' strength by giving them heavier objects that ranged from 25 to 100 pounds. During this testing, every time the primates lifted the weights for the food, the zoologist increased the weight."
- The fourth paragraph reads: "The children and I were surprised to learn that both the chimps and the gorillas could lift the 100-pound weight. We thought that one group would be stronger than the other, but that wasn't the case," Young said.