The first part of this white paper describes an example serious game (called Operation ARIES!) that has completed some very critical steps in research, development, and testing in formal learning environments. We are also fortunate enough to have ARIES marketed by Pearson Education in 2012. The second part of the white paper speculates on important next steps in the evolution of ARIES. Simply put, how can we penetrate the informal learning environments and contemporary social media? How can we launch a viral serious game on par with Angry Birds? We believe that the evolution of this project is similar to other research projects on serious games that have been funded by NSF, IES, and DoD. Developers of serious educational games (that are grounded in science) face major barriers in penetrating the many worlds of informal digital learning.

The evolution of ARIES has indeed passed many major milestones. The components of the game systematically incorporate principles of the learning sciences, including cognition, emotion, and social interaction. The 5-year project has been funded by IES and to some extent NSF. ARIES has shown learning gains on targeted concepts for hundreds of college students. It is among the few serious games that are being marketed by a major corporation, namely Pearson Education. It will be available on the web for widespread distribution. Although we are satisfied in meeting these milestones, we are hardly finished in our mission. We want ARIES to be available to students and adults for extended practice and experiences in informal environments, such as game apps on handhelds. Imagine students playing games of critiquing news stories on bad science and nominating exemplars of bad science to be shared with thousands or millions of players in a community of citizens who want to stamp out bad science.

What is Operation ARIES?!

Operation ARIES (http://aries.pearsoncmg.com/; Cai et al., 2001; Millis et al., 2009, in press) is a game-based environment for helping students learn critical thinking skills and scientific reasoning within scientific inquiry. In addition to acquiring didactic knowledge of scientific methods, students learn 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. It uses animated pedagogical agents that converse with the student. ARIES is coherently organized by a narrative that involves aliens entering planet earth and taking control of the planet by disseminating bad science. The player is in training to become a Federal Bureau of Science expert that identifies these aliens and helps save the planet.

An Interactive Text module teaches students via an E-book (The Big Book of Science), multiple-choice questions, and natural language tutorial conversations that cover core concepts (see the Figure). Each core concept is covered from different viewpoints (e.g., definition, example, importance). The system dynamically adapts the tutorial conversations to the learner’s prior knowledge. These conversations, referred to as “trialogs” are between the human learner and two artificial pedagogical agents (student and teacher). Sometimes the player learns vicariously by observing the student and tutor agents. Sometimes the player gets tutored by the tutor agent and sometimes the player teaches the student agent. Although the trialogs involve natural language interaction in ARIES, it is possible to convert such interactions to more conventional human-computer interaction facilities with menus of optional speech acts and the player selecting an option with a click.
ARIES is very similar to AutoTutor (D’Mello et al., 2010; Graesser et al., 2008) an intelligent tutoring with natural language dialog to help students learn Science, Technology, Engineering and Math topics. AutoTutor guides the student to articulate correct information through various dialogue moves, such as feedback, pumps, hints, prompts, corrections, and answers to questions.

In a Case Study module, the human player and Tracy (a student agent) take turns evaluating cases of potentially bad science. The goal is to identify flaws with a news article, journal article, blog, or other piece of science reported in various media. The natural language of the students and semantic matches to potential flaws are evaluated by algorithms in computational linguistics. In an Interrogation module, players evaluate research by asking questions. The player first reads a summary of research conducted by one of the suspected alien spies. The descriptions do not explicitly signal any flaw so the player needs to ask questions to uncover the flaw. If the study is flawed, then the suspect should be judged an alien. If there is no major flaw, or if the suspect acknowledges a flaw found in the study, the suspect should be judged human.
Next Step in the Evolution of ARIES: Apps in Informal Digital Learning

The current version of ARIES takes 7 to 20 hours of training to complete. However, we would like there to be life after ARIES through apps on handheld devices, iPads and laptops. There would be an unlimited number of new cases for the player to critique and interrogate. The cases would vary in complexity and the player would receive feedback, points, credits, or other forms of incentives in a community of players/learners. The goal of the community would be to stamp out bad science. The goal of the characters would be to advance in the FBS organization. The gamer could have the option of continuing as a solo cadet or joining the force (multi-player option).

This extended practice and skill refinement would be designed to optimize motivation. There are many features of games that optimize deeper expertise and enjoyment.

1. **Multi-player** (against other human or computer players). This includes critiquing other players, challenging other players’ flaws, and deciding if other players get points for flaws.

2. **Collaborative game play** (multiple human players against a weekly expert post or computer). There could be coalitions (individuals, classes, institutions, businesses), comments between players, votes on whether a flaw exists.

3. **Anchored point system**. Points should be anchored in rewards and used to achieve in-game status. In betting, players bet on their answer or the answers of others (encouraging meta-cognition). More points are awarded when flaws are posted and identified than when examples of good research are posted.

4. **Levels or leveling up**. Design the app/game with multiple levels. There are harder texts for harder levels or more difficult questions.

5. **Status**. Players win titles based on performance. For example, one could be the mayor of Confounding Variables.

6. **Player submitted content**. Players nominate examples of bad science in the media and explain why it is flawed. Research descriptions can be posted using a ‘web clipper’. Either experts or other players vote on whether the research is flawed. An expert posts flawed studies weekly.

7. **Fantasy and Storyline**. Members can take the role of aliens or humans. Aliens search for and post flawed research whereas humans search for and post good research. Because good research is more plentiful than flawed research, more points are awarded to flawed research. The Overloads may interfere and reassign the player to the other role based on the mastery level of the player so that the player learns the opposite perspective (e.g., looking for flaws rather than exemplars of good research).

We think that the above descriptions of an extension of a suit of ARIES apps hold many promising features for informal digital learning. The apps will be adaptable for some of the more recent trends in gaming, such as the social networking games evidenced in Facebook and Myspace as well as applications (more commonly known as apps) for portable internet-capable devices such as smartphones and tablets. Applications and social network games often exist as a package or suite of games, which provides the user the choice to decide the length of the game played (such as mini-games or story-based games), the type of advisory competed against (single player, fellow human adversaries, artificial adversaries, and collaborative team effort), and a plethora of opportunities to spend coveted points.

The research descriptions which are posted, evaluated, and discussed would have two origins. One would be descriptions that are created by experts and the game developers. This is the source of the current implementation of ARIES. The other is descriptions posted by the players. These would come from the internet or other sources. Posted studies with flaws would be the holy grail of posts. But because nonflawed studies may end up being substantially more numerous than flawed studies, there will be different ways for players to earn points (leveling up) with exemplars of good science. One
direction is to note aspects of desired features (e.g., used a control group), but another is features not specified that should be addressed (e.g., article did not mention sample size).

A final feature of the game would be the ability for the user to add comments. This may provide those with collaborative tendencies to work with other gamers on more complex cases. The comment feature presumably works well in games that do not require all players to be working at the same time. One might require specific guidelines to avoid internet trolling or gaming the system for points. In this type of collaborative workspace where users could have the option to vote together if a flaw exists in the case presented.

In summary, a suit of ARIES apps would be ideal to teach scientific inquiry skills necessary for the 21st century. It would allow player control, leverage the appeal of social networking sites, and be attractive to players (and educators) in and out of the classroom. Most importantly, it teaches inquiry skills using the same media (the Web) in which most digital natives get their news. Therefore, it has the real potential for transfer of learning necessary for durable learning (Halpern, 2003). Of course, we recognize the challenge of people enjoying or having ‘fun’ as they learn a complex skill from a text-based medium. However, we believe that couching the skills in a story involving a community, along with carefully calibrated points, will be successful.

**Bio:** Art Graesser is a professor in the Department of Psychology and the Institute of Intelligent Systems at the University of Memphis. Having won several awards based on his scientific contributions, Art is an extremely prolific researcher in a number of areas within cognitive and educational psychology. He has authored over 300 hundred peer-reviewed articles, and a dozen books. He and colleagues have developed over a dozen computerized learning environments, including AutoTutor and Operation ARIES!

**Bio:** Diane F. Halpern is the Trustee Professor of Psychology and was the founding Director of the Berger Institute for Work, Family, and Children at Claremont McKenna College. She is a past-president of several national organizations, including the American Psychological Association. Dr. Halpern is internationally known for her work on critical thinking and sex differences. She has won numerous awards for her teaching, and she has authored hundreds of articles and many books, including an eBook in Operation ARIES!

**Bio:** Keith Millis is a professor of psychology at Northern Illinois University. He has won awards for his teaching and he has authored a number of articles on text comprehension and comprehension assessment. He has received many grants on comprehension assessment. Most recently, he served as the project director for Operation ARIES!

**References from the ARIES community:**


