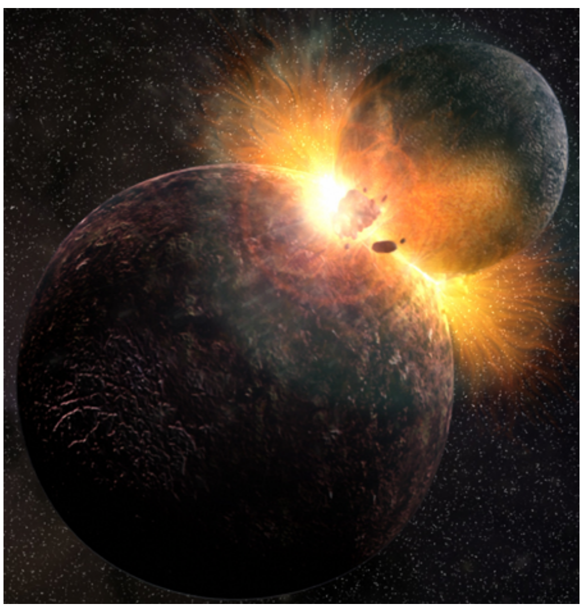
LEARNING LUNAR SCIENCE THROUGH THE *SELENE* VIDEOGAME. D. D. Reese[1] and C. A. Wood[2]. [1]Center for Educational Technologies, Wheeling Jesuit University, Wheeling, WV 26003, USA; debbie@cet.edu, [2]Center for Educational Technologies, Wheeling Jesuit University, Wheeling, WV 26003, USA; chuckwood@cet.edu.

Introduction: Can videogames prepare young people to learn lunar science? Can videogames assess how well young people learn lunar science? The CyGaMEs project built a research agenda to address these two questions (http://cygames.cet.edu). Thus, CyGaMEs joined research initiatives across the nation investigating how instructional game design and assessment can best enhance tomorrow's scientific achievement [*1*]. The CyGaMEs approach to instructional game design and assessment derives from cognitive science analogical reasoning theory that explains (a) how people learn during day-to-day living [*2*] and (b) how scientists make great leaps of intuition and then pass the corpus of established knowledge on to successive generations [*3, 4*]. Using the CyGaMEs approach, we created the web-based game *Selene: A Lunar Construction GAME* (http://selene.cet.edu) and its suite of embedded assessment tools.



Still from CyGaMes Selene Animation Sequence.

Youth aged 9 years old and up play *Selene* via the Internet, any time, any where. Through gameplay, *Selene* players form Earth's Moon and then pepper it with impact craters and flood it with lava flows. Through gameplay, they discover the processes of accretion, differentiation, impact cratering, and volcanism. And through gameplay, the game's assessments measure learning and each player's perceptions of gameplay experience.

We have found that *Selene* gameplay enhances players' ability to infer and apply fundamental planetary science and lunar geology concepts [*5, 6*].

Learning and Assessment: In the CyGaMEs approach gameplay data contains significant information about a player's learning. This is because a CyGaMEs learning object is an analog for experts' scientific knowledge. For example, progress toward the game goal is analogous to progress toward the targeted learning goal. Thus, *CyGaMEs measures of progress toward the game goal are measures of targeted content learning.* CyGaMEs research, summarized below, has demonstrated this.

The CyGaMEs approach translates what the scientist knows, that is, what the scientist holds abstractly within his or her mind, into a concrete world [albeit virtual] that players physically manipulate [*7*]. This makes learning concrete. In day-to-day living, people typically form their conceptual knowledge through a process of informal inquiry [*8*]. Based upon their lived transactions and interactions, they mentally propose hypotheses about how the world works, test the hypotheses, and revise them. CyGaMEs players discover conceptual knowledge the same way. Through inquiry and discovery, they form mental models about the instructional game world. A CyGaMEs gameworld and gameplay are analogs of targeted concepts, and a CyGaMEs game goal is an analog of the targeted learning goal. Learning the game entails learning and applying targeted knowledge, and the game goal drives the player to conduct the discovery and application targeted as the learning goal. Thus, player's gameplay gestures and player progress toward the game goal are measures of learning. Game-based measures are embedded assessments.

In the case of *Selene*, the game is an analog of the second author's mental model of introductory concepts concerning planet formation and development, concentrating on the geological process that modified the Moon as studied through stratigraphy.

Research Methods and Findings: Over the initial years of the project, CyGaMEs researchers have accomplished a number of breakthroughs in gameplay data analysis. Recently, the first author triangulated videos of a player engaged in *Selene* gameplay with gameplay gestures collected as numerical data and the timed report assessment that measures player progress toward the game goal. She demonstrated that the video and the gameplay gesture identify the same moment of learning [*6*]. In this case study, the prototypical learning moment concerns the concept of accretion: that large kinetic energy collisions fragment, while lower kinetic energy collisions accrete. Both gameplay data and the video identified the same learning moment, occurring at the same time. Then, the first author searched the corpus of *Selene* data to identify other cases, exemplars of the same accretion learning moment, and the exact time at which that learning occurred.

The third measure, the timed report, operationalizes player learning as progress toward the game goal, and is measured every 10 seconds of gameplay. Statistical analysis confirmed that the timed report was extremely sensitive to growth in learning, accounting for most of the variance in the model [*6*]. This result demonstrates the validity and sensitivity of the timed report.

In addition to the triangulation, CyGaMEs researchers have demonstrated that an algorithm, programmed to duplicate hand identification of the learning moment, has produced statistical results that replicate those produced by the by-hand identified learning moment.

CyGaMEs analyses have also demonstrated that it is the game itself, and not the environment's video didactic instruction, that enhances player's early understanding of these fundamental planetary processes [*5*].

Player Experience: Learning and Flow: CyGaMEs designed a third embedded assessment, the flowometer, which measures self-reported self-perceptions of experience known as flow. Flow is a state of extreme concentration during which an individual's focus is so directed and invested that the individual may lose track of time and be unaware of distraction [*9, 10*]. Flow is a state of extreme productivity, and it is intrinsically rewarding. Optimal, balanced, and relative high levels of skill and challenge indicate a person is in the state of flow [*11*]. According to Mihaly Csikszentmihalyi [*12*] (developer of flow theory), during learning, challenge is higher than skill. Thus, by definition, people should not experience flow while learning. Flow theory defines seven other states of experience, also according to relative self-reported levels of skill and challenge: apathy, boredom, routine expertise [like a rock climber on a familiar cliff face, also labeled relaxation,], control, arousal, anxiety, and worry [*13*]. Csikszentmihalyi suggested that people learn in a state of arousal [*12*]. However, scholars have yet to establish the relationship between learning and the eight flow channels.

Using the flowometer and two phases of data collection, we have established baseline levels for the eight channels of flow during *Selene* gameplay, instruction, and animations, and other components of the environment [*14, 15*]. As our player population and database grow, we will combine flow, gesture, and timed report analyses. We hope to identify, for *Selene* at least, the correspondence between flow and game-based learning.

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