Background

The NASA-sponsored Classroom of the Future (COTF) at the Center for Educational Technologies® (CET) at Wheeling Jesuit University in Wheeling, WV, will measure learning and flow by programming the game software to track each player's decisions and actions while playing the computer game. The player's actions and decisions are the player's gameplay. COTF will also collect demographic data about players in order to determine how they interact with gameplay.

During FY07, the COTF is planning collection of data within two game types: (a) the NASA game prototype and (b) experimental games. Currently, all COTF experimental games studies concern one game, *Selene*. COTF is collaborating with Georgia Tech and the University of Florida to assess learning in the *Selene* game about lunar impact cratering and volcanism. The game is in development, scheduled for usability testing (playtesting) in mid-April and for experimental studies starting in May. COTF also is planning two types of data collection, assessing gameplay: (a) usability testing (by COTF employees) and (b) the game research study. The goal of the research is to develop and study our data collection instruments and data analysis techniques related to assessing learning and flow in games.

COTF will also build on COTF expert review by nine CET/COTF staff conducted in FY06 that matched commercial, off-the-self (COTS) gameplay with learning outcomes. Games experts will be trained and then asked to study COTF definitions for learning types and game types and then rate each type of game genre for its ability to promote each type of learning objective. Experts will write a rationale for why they evaluated the games as they did. The document entitled "COTF_outcomes_genre_info.doc" contains the chart that experts will complete and a sample, completed expert narrative.

Below, we provide a detailed description of the gameplay tracking as applied to the FY07 games and projects (data collections 4, 5, 6, and 7). During FY08 and FY09, COTF will conduct the same data collection procedures to measure learning and flow in games, using the FY07 games and modifications of those games. It is possible that NASA, NASA partners, and academic or private organizations might use the COTF methodologies to design electronic games and ask COTF to study affordances for learning and assessment. If so, these additional experimental games (in addition to *Selene*) would be subject to the same data collection procedures as *Selene*. So far, COTF has not identified any additional experimental games.

The NASA Game Prototype

The NASA game prototype will involve 20-30 minutes of gameplay in two contexts: the International Space Station and moon exploration. The goal of the game is to promote players' awareness of the NASA mission in support of NASA Strategic Plan education outcomes 2 and 3, which involve inspiring and engaging students and the public. Two types of data are collected. The first will measure learning, that is, change in game player's knowledge of the NASA mission within a targeted area to be determined by project leadership. The second will measure how the game affects the player's flow experience.

<u>The Experimental Games (i.e., *Selene*)</u>

Development of partnerships is one of NASA's exemplary program criteria. COTF has begun to develop a network within the gaming community because of its dissemination of research of game literature and its theoretical approach to game design and assessment. Currently, two universities are partnering with COTF to investigate learning in games: Georgia Institute of Technology and the University of Florida. Other scholars at several universities are also interested in supporting the COTF games research agenda: Vanderbilt, Western Illinois University, Arizona State University, University of Illinois at Champaign-Urbana, and Purdue. A private company, Forterra Systems (http://www.forterrainc.com/), is also very interested in the game design and assessment technologies COTF has disseminated. Although current NASA-funded partnering plans concerning the *Selene* game involve only two universities, other opportunities may develop over the course of this PRA period. COTF will work with organizations developing games (e.g., game development companies, universities) to build hooks into the games to allow for assessment. The generalizability of COTF findings will be increased if *Selene* studies replicated (operational replication, replication with extension, and constructive replication). During the *Selene* studies, COTF will experiment with two types of assessment measurement tools and techniques. The first will measure learning, that is, change in game player's knowledge of targeted science, technology, engineering, and mathematics (STEM) concepts. The second will measure how the game affects the player's flow experience.

<u>Two Types of Data Collection for Both Games</u>

Both games will be usability tested (playtested) during development and studied during experiments conducted after the games are completed.

1. Usability Testing (Playtesting)

   A small group of paid participants (nine adult individuals working part-time for COTF) will participate in usability testing by playtesting the NASA and COTF game prototypes and the NASA and COTF game prototype assessment instruments (see following description of embedded assessments). COTF will pay playtesters $7/hour for about 40 hours of participation. Playtesters may work on the games from the COTF facility or another designated location. Data will be collected in person and via a server. Playtesters will be observed during gameplay, and observations will be recorded by the researchers, who will also interview playtesters in both focus group and one-on-one settings.

   Interview questions:
   A. What worked in this game?
   B. What didn't work?
   C. How would you change what didn't work?
   D. What was fun in playing this game?

E. What wasn't fun about playing this game?
F. How would you change what wasn't fun?
G. Did you feel in control?
H. Did you feel that your decisions impacted your chance of success in the game?
I. What did you learn about [targeted concept]?
J. How did playing the game help you to learn this?
K. Did the pace of your gameplay sometimes slow down?
L. When did this happen?
M. Was the game as engaging when gameplay was slow as when it was fast?
N. What was your level of skill at playing the game?
O. Were there times when your level of skill was greater or less than what you needed to succeed in playing the game?
P. What was your level of challenge in playing the game?
Q. Were there times when the level of challenge was too great or too low? If so, how did you feel when this occurred?
R. What did you like about the game?

COTF has used game design (Fullerton, Swain, & Hoffman, 2004) and instructional design literature (Smith & Ragan, 1993) to set the number of usability testers (playtesters) at nine. According to Fullerton, playtesting is the single most important game design activity (p. 196). Technically, playtesting is not the same as usability testing. Playtesting allows the designer additional insight into how the players experience the game. It is a component of iterative design (test, evaluate, and revise). Both group and individual dynamics are necessary to test game effectiveness. Historically, four individuals can provide sufficient one-to-one (player to researcher) information in early stages of instructional design. Field trials are conducted with about 30 individuals representing each targeted audience. COTF will not conduct a field trial of the *Selene* game. COTF budgeted to employ nine playtesters. This will allow the researchers the flexibility to study <u>individuals</u> at play within the game, <u>focus groups of three players</u>, and larger group (<u>nine members</u>) open discussion. Given the project time constraints (only about two weeks) and responsible use of budget dollars and financial resource constraints, nine playtesters will allow COTF grouping flexibility but maintain a manageable sample size that will provide informative data without overwhelming the analysis with too much data to be processed, evaluated, and reported to the game design team at Georgia Tech. A playtester pool of nine affords breakout into smaller groups of three.

2. Game Playing

COTF plans to collect data from about 1,000 game players for each game, ranging in age from middle school to young adult (about college age). These game players will access the games online. Data will be collected online. We estimate that game players will take about one hour to play the game, which includes completing the embedded study.

The use of data-mining techniques to measure changes in players' mental models and flow experience through gameplay embeds assessment within the game. This supports a reduction of the burden on the public. These players will not complete tests external to the game.

A description of the study instruments follows.

Data to be collected.

COTF will investigate the games' abilities to enhance players' flow experience during gameplay. It will also measure players' growth in targeted knowledge. For the NASA game targeted knowledge will concern the NASA mission. For *Selene*, targeted knowledge concerns a STEM domain: lunar processes of impact cratering and volcanism. For the NASA game, COTF will also collect survey-like data to measure players' engagement and inspiration toward the NASA mission.

COTF will collect:

- **Login identity.** Each player will create a login by creating a fictional user ID and password. The fields: User ID, User Password. There will be no registration form.
- **Informed consent for adults.** Login will be preceded by the requirement of completing an informed consent form. The informed consent form will stipulate that participants must be 13 years of age or older. The informed consent form consists of the description of the study, contact information for the researchers and Wheeling Jesuit University Institutional Review Board, and selection of a box that the individual agrees to participate in the study. It does not collect personally identifying information. This URL will not be advertised to a youth population community. Only adults will be recruited for this URL.
- **Informed consent for minors.** This involves recruitment of minors, ages 13 and up. COTF will use the Jesuit network and other youth-oriented organizations (e.g., schools, church groups, 4-H, girl scouts) to recruit responsible adult leaders (e.g., teachers, scout masters, 4-H leaders). These leaders will recruit and be responsible for the logon for youth participants. Each leader will receive a logon and password. They will identify a sample population or 25 or fewer minors. They will distribute informed consent forms to legal guardians of the minors. The parent/guardian's informed consent form consists of the description of the study and contact information for the researchers and the Wheeling Jesuit University Institutional Review Board. These are passive consent forms. Parents do not return them. Legal guardians will communicate their permission verbally to the recruiter. After leaders confirm student participation with parents, they will distribute temporary logon passwords to their group of students. The students will use these for initial logon and then register themselves by creating a unique password and user ID. There will be no database connection between the leader-provided logon (used to create the individual students' logon) and the student's logon. The game will use the student logon information to connect gameplay activity within each individual student, and this logon will be retained by the game system. No identifying information will be collected about the game participants. The logon information will be retained by the game database to

allow players to re-enter the site for additional gameplay activities. Retention of the logon will allow the researchers to track players' interest, as afforded by the game.

- **Demographics.** As the players register online to play the game, COTF will collect age, sex, ethnicity, race, school grade level, academic grade point average, mother's highest level of education, father's highest level of education, city, county, state, and ZIP code from each participant. This will be collected within the logon page. No personally identifiable information will be collected.
- **Critical incident: Tracked level of flow.** The NASA game will track playtesters' actions as they play the game. Actions will be tracked by the game when they respond to areas of gameplay hypothesized to enhance a game player's flow experience. These gameplay areas are called critical incidents. They concern (a) goals, (b) feedback, (c) a sense of control in a situation in which the outcome is uncertain, and (d) level of challenge. The software will measure player responses for (a) level of skill, (b) rate of response, and (c) gameplay decisions made in response to choices. The software will track the attributes of each tracked gameplay response situation: (a) type of goal (learning outcome), (b) type of feedback, (c) degree of player control, (d) type of cognitive task (experiential or reflective), (e) level of cognition (the amount of time it takes player to complete a response to the situation—for example, a click of a mouse to select an object compared to navigation of a maze to locate an object). Each tracked experience will be tagged for the time it is measured (how long has player been playing) and will be assigned a unique experience sampling ID number and an event experience ID number that will be used to categorize experiences and correlate them with prompted experience data (next item).
- **Critical incident: Prompted level of flow.** As described above, the program will track players' gameplay responses at critical incidents within the gameplay experience. Near the end of each critical incident set, the program will prompt the player to record the player's perceived level of skill and challenge. The prompt will be designed to match the gameplay story and context, but will ask only two questions: level of skill and level of challenge (see Figure 1). Player data will resemble a Likert scale, but players will respond using a data collection interface embedded within the gameplay context. We provide two examples below, but the actual structure of the interface will be determined during game design.

> *Example 1:* The game could request players to respond on a 10-point Likert-like scale.
>
> *Example 2:* The interface could use a slider system, and the player could represent level of skill and level of challenge by adjusting the slider from a low level to a high level.

Participants will respond to two pop-up prompts. . .

	Low								High
How **challenging** is the activity?	1	2	3	4	5	6	7	8	9
How **skilled** are you at the activity?	1	2	3	4	5	6	7	8	9

Figure 1. The two items from the Experience Sampling Method (ESM) form used to indicate level of flow.

- **Critical incident: Growth in targeted knowledge.** Gameplay will be designed to support targeted knowledge. The game will track player gameplay (e.g., decisions) at critical events within the game that require the player to engage in actions that apply concepts, procedures, or problem solving targeted as learning outcomes. Data for each knowledge growth critical incident will be collected twice. The first collection will serve as the pretest, and the second will serve as the posttests.

The following section contains the current iteration of the Selene design document. It will provide reviewers with a summary of the game content and scope as well as the plan for data collection.

Moon Game Design

Selene

Selene is an educational game designed as part of an experiment on learning. There are two core design concepts for the game:

- The content of the game must be closely aligned with the core principles being taught (as illustrated on the large concept map: see image within file “selenology11 Final 2007March02.gif” and smaller version of the concept map on page 15 of this document).
- The game must connect to a database (via HTTP) and log information on the players.
- We will use the game to create a movie for the control group to avoid creating graphics/audio discrepancy between the two groups.

To this end, we have split our original design into several modules:

1. Solar System Accretion
2. Moon Accretion and Differentiation
3. Volcanism
4. Surface Features

Each module will have its own goals, and information from early modules should inform the game state of later modules [i.e., the choices you make in Stage 2 (Moon Accretion) should affect how cratering and lava flows perform in Stage 4 (Surface Features)]. Some type of scoring system will be needed to inform players of their performance (we've discussed using the school-centered system of A through F), which should also allow them to go back and repeat earlier stages if so desired.

In our current design, we also wish for each stage to increase in scale of interaction. The first stage will be more activity-like, while the final stage will be the most fully featured and "game-like."

Data Reporting

The reported data will concern three main areas: how well the player's mental model matches the intended model, the player's gestures, and the player's flow. Timed data reports occurring as a result of gameplay will concern the mental model and possibly flow. Flow can also be reported with a prompt. These reports will be stored during each stage and reported all together at the end of a stage. Each report will include the following:

- Player ID
- Game level identifier
- Stage identifier

Timed reports
The actual shape this will take will largely depend on the final design of each module. We do have a preliminary data model. In each stage the final goal will be a certain level of "Mooniness." Over a given increment of time (this variable can be easily tweaked when implemented, but for now we'll say every 15 seconds), we should be able to measure whether the player has either moved toward the goal (+1), away from the goal (-1), or stayed the same (0).

The data stream for "Mooniness" would only be one variable we would track, but the total score would be the sum of all +/-'s throughout the game. Looking at a sample of only the last 5 or 10 values should tell us whether the player is performing well or performing poorly. For example, in the following streams:

- [+ + - + 0 + + + + +] Total: 7 Inference: Player performing well.
- [- 0 - - - 0 0 - - +] Total: -5 Inference: Player performing poorly.
- [- + + - 0 - 0 0 + +] Total: 1 Inference: Player acting randomly.

For each timed report, the following data will be included:

- Timed report
    - Time stamp
    - Measure of goal attainment
    - Player's perceived skill level (if this can be integrated into gameplay, challenge too?)

In the database, the identifier will be associated with other attributes determined beforehand, once the game is designed. For each activity, these may include:

- Associated attributes
  - Goal type (learning outcome)
  - Feedback type
  - Degree player control
  - Degree of certainty
  - Type cognitive task
  - Experiential
  - Reflective
  - Level of cognition
  - Active or passive
  - Challenge level
  - Feedback
  - Gesture category

Gesture Reports

Gesture reports will include the following data:

- Gesture report
  - Gesture identifier
  - Time stamp
  - Concept numbers
  - Relational rules

For the most part, the ways that these reports are relevant to the study will be analyzed later.

Prompted Reports

Ideally, measures of flow will be integrated into the game. We can’t be sure if this is possible at this early stage, so we are planning on prompting the player to report their perceived level of skill and their perceived level of challenge in one of two ways. One is to have two sliders, providing a more detailed and accurate sort of Likert scale. The other way is to have a two-dimensional “flowdometer” with skill on one axis and challenge on the other. This chart can be annotated with descriptions of states associated with each area of the chart. The data reported from these prompts will include:

- Activity identifier
- Perceived level of skill
- Perceived level of challenge

In the database, the identifier will be associated with other characteristics as in the timed reports.

Mooniness

The term mooniness is not meant to imply similarity to Earth's moon. Though the creation of our specific moon would be a neat (and possibly difficult) activity, the underlying principles of planetary geology are the same for ANY moon. The player is, therefore, creating *a moon* and not necessarily *our moon*. Mooniness, therefore, implies that the player's moon object complies with the laws of physics and the other underlying concepts.

Visual Appearance

Though this is an educational game, we would still like to make it visually appealing. This is a somewhat lower priority, though. The order of priorities is:

- Teach core concepts.
- Be fun to play.
- Be visually appealing.

As most of our games are procedural in nature, they should be fully functional with "programmer art." Once the crux of the engineering has been undertaken, it should be relatively easy to go back and replace our functional drawing routines with "prettier" graphics.

Transitions

Though it is tempting to smoothly phase from one stage to another from within the game (through a sort of "zooming in"), from a production point of view it makes more sense to use static splash screens to transition from stage to stage. As each stage has separate interactions, this will also act as a segue from one interaction to another.

Player’s Mental Model

The game is designed to support growth of targeted understanding: Gameplay gives lived experience answering investigation question through gameplay. The game will incorporate 101 concepts.

At the microscopic level, all propositions specified in the map are learning goals.

Example:
Partial List of Propositions for **<u>Stage 1: Solar System Accretion</u>**

- **Projectiles** have **mass.**
- **Projectiles** have **velocity.**
- **Mass** determines **kinetic energy.**
- **Velocity** determines **kinetic energy.**
- **Collisions** are characterized by **kinetic energy.**
- **Kinetic energy, if high,** causes **debris.**
- **Kinetic energy, if low,** causes **planet formation.**
- **Planet formation** acts as a **vacuum cleaner.**
- **Vacuum cleaner** depletes **debris.**
- **Debris** acts as **projectile.**

Stage One: Solar System Accretion

Current module concept—will be revised.

This module is designed to teach players about accretion in the early solar system. Play will begin with a star in the middle of the screen and a random distribution of particles orbiting the star. A physics model will be in place, causing particles to attract to each other and form small planetesimals. Players will have the ability to "spray" new material into the system, though this amount will be finite to represent the finite amount of starting material in a given solar system. Performance will be measured based on how many objects of a given size can be created with a stable orbit.

Prototypes

- http://steel.lcc.gatech.edu/~jgilbert3/selene/solar_system_accretion/index.html

Interaction

Current module concept—will be revised.

As this is the first (and simplest) activity, we want to keep the interaction very simple. The mouse will act as a "debris brush," allowing players to "spray" more particles into the system. The size and shape of this brush will be set (and based on our own tests). As players add more debris, a reservoir will deplete. When this reservoir empties, the activity will end, and players will move on to the next activity.

Goal

Learning goal is to answer the investigation questions:

- How do planets form?
- How did the Earth form?

Key understanding:

- The Earth grew out of small pieces of stuff that came together through low-energy collisions.

Underlying science:

- High-energy collisions cause fragmentation; low-energy cause accretion.

Game Goal

Current module concept—will be revised.

At the simplest level, the goal of players is to use up all of the material. At a higher level, the goal is to create as many stable orbiting planetesimals (a particle of an arbitrary size) as possible.

Data (for reporting purposes)

Current module concept—will be revised.
It should be relatively straightforward to check if players have moved further toward the goal of an A or if they have regressed toward an F. This progress will be reported in 10-15 second increments along with other gestures performed by players.

Stage Two: Moon Accretion and Differentiation

In this phase, set just after the massive collision between "Moon" and "Earth," players take the role of a large orbiting body, which will become a moon. As this object rotates around the proto-Earth, it gathers up the other debris. The players' job will be to choose which debris to gather up. To create a proper moon, players will need to grab the correct proportions of material (metal, ice, low-density and high-density materials). Each "grabbed" object adds to the total mass of the player/moon as well as the heat of that object's impact. Meanwhile, the impact of these objects will add heat, melting the material in the moon and allowing for differentiation. This interaction will be similar to pushing around masses in a lava lamp. Players can push these blobs around to get a properly differentiated moon as long as there's enough heat.

Interaction

Unlike the first prototype where players are much more free to spray randomly, in this game players will actually need to pay attention to the objects surrounding them. Objects will float past the screen, and players will be free to click or ignore as they see fit. Clicked-on objects will be sucked into the gravity of the proto-moon, adding both its mass and the heat of its collision. Within the moon the interaction will mostly involve clicking on high-density blobs. This will be the first game with a time-pressure (although not a hard one), as cooling and a diminishing source of projectiles eventually make differentiation impossible.

Goal

Learning goal is to answer the investigation question:

- How did the moon form?

Key understanding:

- An extra large collision at the end of accretion ejected Earth material that re-accreted to make the moon.

Underlying science:

- High-energy collisions cause fragmentation; low-energy cause accretion.

<u>Transition</u>

Why did the early moon melt?

Moon Differentiation

Learning goal is to answer the investigation question:

- How did layers of the moon form?

Key understanding:

- The moon was totally molten; the heavy stuff sank, and the light stuff floated.

Underlying science:

- Density and gravity determine position in a viscous, heterogeneous mixture.

Game Goal

Current module concept—will be revised.

The simple goal of this exercise is to collect enough mass to be considered "moon-sized" (actually an arbitrary value that we'll set). At a higher level, the goal is to grab materials in the proper proportion so that the end result will have the properly sized core and mantle. Another goal will be to get a properly differentiated moon, with a dense core, a medium density mantle, and lighter density material evaporated away. Choices in this game will also affect the overall density of the moon, which will affect how much gravity is present (and, therefore, how ejecta and lava behave). This phase will end when the moon has cooled to a certain degree.

Data

Current module concept—will be revised.

Same as Stage One—measured in 10-15 second increments of progress. It should be relatively straightforward to measure how close to the solution the player is and report whether or not the player is getting closer or further away from this state. This solution has two parts: a good proportion of materials and a well-differentiated moon.

Stage Three: Volcanism

This stage will happen concurrently with Stage Four for a while, until the moon cools to the point of having no more lava flows. The player will manage the lava flows that fill mare created by large cratering created in Stage 4.

Goal

Learning goal is to answer the investigation question:

- What are the dark splotches on the moon?
- Why, how, when, and where did volcanism occur?

Key understandings:

- Why: Radioactive heating occurs in the upper mantle.
- Why: Lunar volcanism is due to radioactive heating in the upper mantle (and not differentiation).
- Why, how, where: Magma is less dense than surrounding rocks and buoyantly rises toward the surface, preferentially along basin fractures.
- Why: There are two types of volcanism: explosive[1] and effusive (flowing)[2].
- How: Lava flows travel down slope because of gravity.
- Dark splotches: Lava flows create the mare.
- How: The structures that the lava flows form depend on the nature of the magma.
- When: Volcanism continues until the moon freezes (cools).

Underlying science:

- Radioactive heating causes melting.
- Buoyancy[3] and gravity control the rise of magma and the flow of lavas.

Game Goal

This phase will end when the moon cools completely and no longer has lava flows. A possible goal would be to have mare completed before this takes place so that detailed cratering can occur on top of them.

Data

Data reported in this stage will include a measure of goal attainment based on whether or not mare are filled in. Also, an understanding of cooling can be determined based on whether or not the player continues to try to fill in mare after the moon “dies.”

Stage Four: Surface Features

Now that the moon has been "created," this stage is actually the main area of gameplay. Given the blank canvas of a moon (with the properties defined by the earlier stages), the player now creates his or her own set of surface features by throwing rocks of different sizes at the moon at variable speeds. The impacts (and the impact angles) will determine what type of crater is created. **[**Lava flows will either occur as a result of the players’ actions in stage three, which will be played concurrently. Lava flows will occur as a result of these impacts until the moon cools.**]** We hope to make the overall experience a relaxing, spacey, procedural drawing game rather than something more akin a plate-spinning game. Though this stage will not have a concrete "End" state, the fall-off of volcanism and meteor activity will be modeled. This should create a "soft" game in which the amount of stuff going on is not sufficiently engaging for players to continue.

[1] Only a small amount of volcanism is effusive because there was only a small amount of volatiles left after moon accretion.

[2] Most lunar volcanism is effusive.

[3] Buoyancy is the rising of less dense material within a viscous medium.

Interaction

At its core, this game will be a projectile game. Players will have a simple method of choosing their projectile size and speed. After a projectile has been chosen, players will "aim" the meteor at the moon and "fire it," accounting for the distortion that will be caused by the moon's gravity. Each "size" of projectile will have its own rate of recharge (the amount of time before a projectile of that size can be thrown again). Large objects will be common early and increase in rarity as the simulation progresses.

Goal

Learning goal is to answer the investigation question:

- What controls the size and shape (morphology) of impact craters?
- What determined the scenery (stratigraphy) of the lunar surface?

Key understanding:

- Craters: The amount of energy of the impact controls the size and shape (morphology) of impact craters.
- Craters: The strength of the target rocks modulates morphology.
- Surface: Impact craters redistribute subsurface material across the surface.
- Surface: Lava flows and cratering intermingle.
- Surface: Fragmented materials darken with time.

Underlying science:

- Kinetic energy is dissipated by modifying rocks in various ways.
- Kinetic energy is expended in breaking, melting, and moving rocks.
- Stratigraphy is the record of time sequence of events.

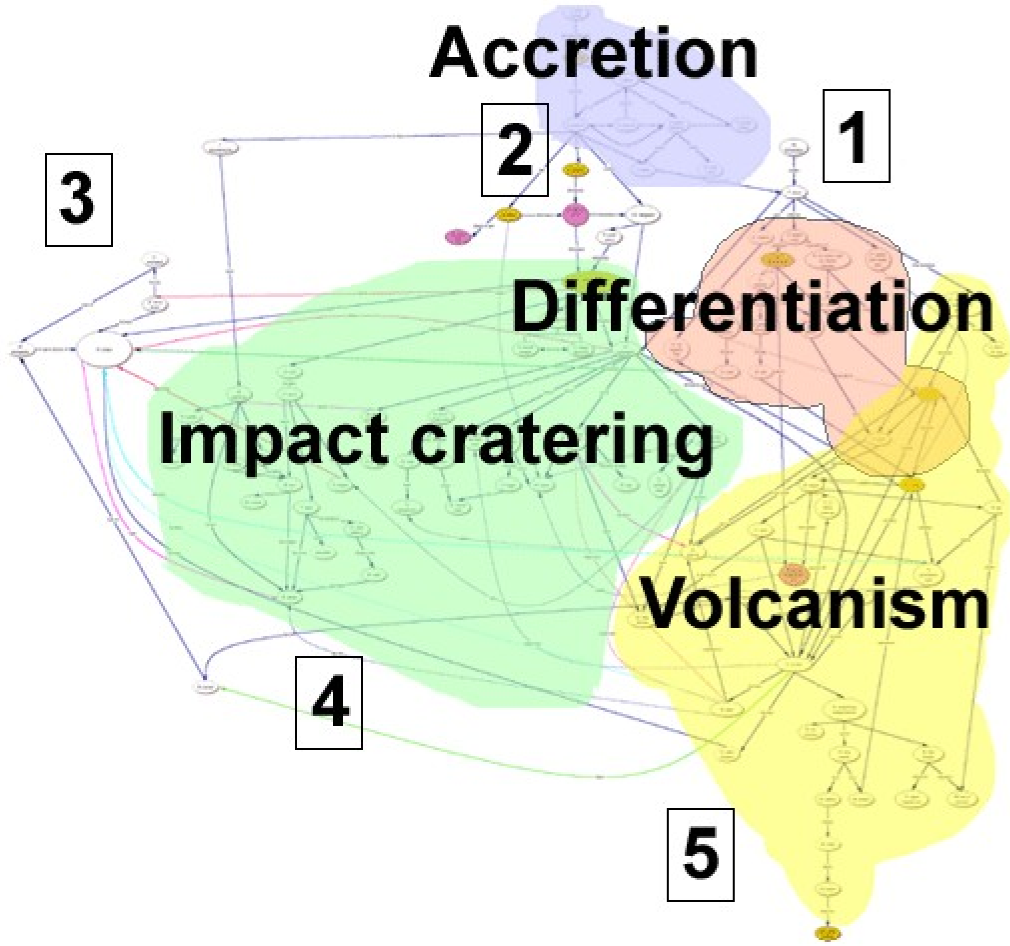
Game Goal

This final stage will be most "sandbox-like." As such, there may not be a concrete goal. The actual goal of this stage will be to learn how various external forces shape the surface of the moon and how a sequence of craters overlaps each other.

Data

In this stage it will probably be more useful to report the gestures of players. What types of objects are they selecting? Are they creating new features in the blank areas or are they overwriting existing features?

The following section contains a diagram of the 101 game concepts (in ovals) and the relational structure of the content, and the module and region labels. This is followed by a table that lists all game concepts and the current assignment of concepts to game modules or regions. Game stages are developed for game modules. The game modules are accretion, differentiation, volcanism, and impact cratering.



TARGET CONCEPT	REGION OR MODULE
01. solar system	Accretion
02. accretion	Accretion
03. projectile	Accretion
04. collisions	Accretion
05. debris	Accretion
06. vacuum cleaner	Accretion
07. micrometeorite	Region 1
08. planet formation	Accretion
09. velocity	Region 1
10. mass	Region 1

11. overturned	**Region 2**
12. power law	**Region 1**
13. KE=1/2 mv^2	**Region 1**
14. impact	**Region 1**
15. Earth	**Accretion**
16. other worlds	**Accretion**
17. moon	**Differentiation**
18. Selenology	**Differentiation**
19. point source	**Region 1**
20. lighter mid-density	**Differentiation**
21. rotation	**Differentiation**
22. magma ocean	**Differentiation**
23. lower layers	**Region 2**
24. scum	**Differentiation**
25. energy dissipation method	**Cratering**
26. differentiation	**Differentiation**
27. surface area/volume ratio	**Differentiation**
28. stratigraphy	**Region 2**
29. surface	**Region 2**
30. competition	**Cratering**
31. minerals	**Differentiation**
32. greatest density	**Differentiation**
33. radioactivity (radioactive melting)	**Differentiation**
34. natural strength	**Cratering**
35. energy deposit	**Cratering**
36. topography	**Cratering**
37. no magnetic field	**Differentiation**

38. core	**Differentiation**
39. heavier mid-density	**Differentiation**
40. low atomic mass/low-density elements	**Differentiation**
41. about .56 bya	**Differentiation**
42. rock	**Cratering**
43. to space	**Differentiation**
44. volatile	**Differentiation**
45. density	**Volcanism, Differentiation**
46. gardening	**Cratering**
47. ejecta	**Cratering**
48. simple bowl crater	**Cratering**
49. D=15-45km crater	**Cratering**
50. floor fractured crater	**Cratering**
51. complex, D>45-300 crater	**Cratering**
52. basin 300-600 km	**Cratering**
53. multiple rings	**Cratering**
54. multiring basin > 600 km	**Cratering**
55. mantle	**Volcanism, Differentiation**
56. regalith	**Cratering**
57. meters	**Cratering**
58. mixing	**Cratering**
59. excavating	**Cratering**
60. D<15k	**Cratering**
61. floor	**Cratering**
62. walls	**Cratering**
63. central peak	**Cratering**
64. terrace	**Cratering**

65. ring	**Cratering**
66. magma	**Volcanism**
67. cooling	**Volcanism**
68. 1 meter	**Cratering**
69. rays	**Cratering**
70. blanket	**Cratering**
71. crater halo	**Cratering**
72. slumpblocks	**Cratering**
73. bigger	**Cratering**
74. vents	**Volcanism**
75. 2.5 billion years ago	**Volcanism**
76. gas	**Volcanism**
77. glass	**Cratering**
78. gravity, F=g(m1m2)/r^2	**Volcanism**
79. pyroclastics (ash)	**Volcanism**
80. mascons	**Volcanism**
81. solar radiation	**Cratering**
82. deep fracture	**Volcanism**
83. buried	**Volcanism**
84. 3.7-1 bya	**Volcanism**
85. albedo	**Cratering**
86. solid	**Cratering**
87. lava flow	**Volcanism**
88. normal	**Region 3**
89. mare	**Volcanism**
90. morphology (characteristics)	**Volcanism**
91. other volcanics	**Volcanism**
92. low viscosity	**Volcanism**

93. lava tunnels	**Volcanism**
94. flow (length)	**Volcanism**
95. interior	**Volcanism**
96. exterior	**Volcanism**
97. rapid eruption rate	**Volcanism**
98. lots of pressure	**Volcanism**
99. warm	**Volcanism**
100. hollow	**Volcanism**
101. moon settlers	**Region 4**

References

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