

## Preview of Award 1203090 - Final Project Report

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Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	Lucien Vattel

## Accomplishments

### \* What are the major goals of the project?

**Summary:** The overall goal of the project was to design, build, and iterate on a series of embodied and simulated geoscience games, exploring the extent to which interactive, simulated, and embodied experiences can engage students and promote learning in historically challenging geoscience concepts. Through these types of experiences, we wanted to see how effective they were in having students develop a deep conceptual understanding of geoscience topics as opposed to memorizing discrete science facts.

Our initial hypotheses were:

1. Students would be highly motivated to learn about geoscience if it were situated within specific experiential and embodied contexts, with well-developed simulation, embodied, and game-based learning environments.
2. Such environments allow students to deeply interact with the content domain by fostering conceptual understanding and understanding of the processes that scientists engage in.

With these hypotheses, we sought to create a series of games that would provide an intuitive and self-evident understanding of the structure of the earth and its system of processes over deep geological time. Our goal for the games was to integrate a series of motivating interactions and differentiated instruction with convenient, flexible controls to provide immediate, varied feedback.

We were not only interested digital games and simulations, but also physical modalities as a means to test our hypotheses. For example, when we looked at how to create an embodied learning game, we thought to ourselves, “Why don’t we use our bodies to teach the process of accretion and the principles of gravity in a field game?” In parallel with the physical exploration, we explored a digital physics simulation, *Universe Sandbox*, where students could control specific variables (e.g., mass and orbital patterns), witnessing how the changes they made would affect the system. We then decided to combine our two previous experiences (field game, *Universe Sandbox*) to examine what would happen if we merged full body movement, simulation, and motion tracking using the *SMALLab* technology. From there, we investigated how we could map very specific hand motions (e.g., hands pulling apart and coming together) to how geological systems, such as plate tectonics, actually occur (e.g., divergent and convergent boundaries) by utilizing the *Leap Motion Controller*.

**The project was proposed to encompass the following phases.**

### **Phase 1: Expert Roundtables: Content Domain Analysis and Task Modeling: 100% Complete**

Project PIs, lead game designers, and academic officers collaborated with Bill Nye the Science Guy, LucasArts, the content expertise of CalTech to participate in domain analysis in order to thoroughly document all core definitions, concepts, and processes associated with the target learning standards and the field of geoscience.

### **Phase 2: Domain to Game Mechanic Mapping: 100% Complete**

The GameDesk project team examined the affordances of gameplay, game design, and embodied learning that map well to the target conceptual and procedural learning outcomes. Questions that drove this phase include: What kinds of visualizations capture and communicate the concept of interest? What features of the technology can be mapped to the concept, such as the ability to speed up time to make patterns more evident, or to simultaneously and dynamically represent a phenomenon in multiple ways (e.g., thermal maps and linear equations)? What kinds of human physical motion might reinforce or parallel the concept? For instance, the motion of shaking a rope could capture the relation between wavelength and frequency.

### **Phase 3: Prototype Design and Development: 100% Complete**

Full project team developed game ideas, stories, and engaging gameplay that naturally supported these concepts. This phase entailed determining what will make the game and simulation experience content-relevant and consistently engaging. With respect to game mechanics, we crafted sets of goals and obstacles that could express a geoscience concept or require a player to learn or apply the concept. Connecting game mechanics to real-world contexts was another defining feature of the process. We brainstormed what kinds of game mechanics a player could enact that would provide evidence of learning. Finally, we considered the ways that these learning outcomes are typically assessed, and integrated gameplay activities that were likely to transfer to successful performance on more traditional assessments.

### **Phase 4: Science Content Revisions: 100% Complete**

Content team and experts ensured that accuracy has been retained in the design process. This review consisted of a set of “check points” including considerations such as: What specific elements of game play will lead to the desired learning outcomes? Does the game consistently engage learners? What kinds of data will the game generate that can be used to make assessment inferences?

### **Phase 5: Game Development: 100% Complete**

Game development proceeded to be readily tested.

### **Phase 6: Small Group User Testing: 100% Complete**

Games were playtested in small, focused pilots with the target student and teacher audience. In this phase of the project, we conducted small-scale pilot tests of the games at GameDesk studios to confirm whether the intended conceptual learning was happening or not. This was a critical step for the success of the project, which depended on the users’ ability to gain conceptual understanding from the games. Preliminary test of main hypotheses occurred.

### Phase 7: Data Gathering and Analysis: 100% Complete

Revisions were made to the games based on data gathered during pilot testing. Playtesting relied primarily on qualitative observations and interview data.

### Phase 8: Larger Group Focus Testing: 100% Complete

The games were tested in a classroom setting at a partner school with the target student audience, seeing how the games would actually be implemented and used in the classroom with a full class of students and teachers. Qualitative observations and interview data were recorded to test main hypotheses once more.

### Phase 9: Revisions: 100% Complete

Student interview data, observation data, and teacher interviews were analyzed from the larger group focus testing and the project team made revisions to the games.

### Phase 10: Pilot Evaluation: 100% Complete

A large-scale evaluation was conducted at seven middle schools in Los Angeles County to test our main hypotheses. Three of our games were evaluated and 300 students were tested. Evaluation was conducted using a staggered experimental design, with data collected regarding students' STEM knowledge as well as science career aspirations and attitudes. Students completed pretests tapping their conceptual knowledge, STEM attitudes, and topic interest. Participants' situational interest were assessed *in situ* during implementation. All measures were re-administered immediately following the intervention. **NOTE: An evaluation report of the results was generated and is attached to this report under "Products".**

### Phase 11: Final Revision, Curriculum Development, & Media Production: 100% Complete

The games were modified based on the results of data analysis. The project team made final revisions to the module based on pilot test. Data from the testing analyzed the effects of the module on students' geoscience learning and attitudes. The curriculum team extracted best practices from pilot implementation and user feedback to develop curriculum around all games. Video media were produced to document the project. **NOTE: The full curriculum is attached to this report, and we've provided links to our videos. Both can be found under "Products".**

### Phase 12: Dissemination: 100% Complete

The games and curriculum were packaged for national dissemination and distributed on GameDesk's website, Educade. **NOTE: Links to our games and curriculum are listed in the field entry "How have the results been disseminated to communities of interest?"**

### \* What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?

Major Activities: Below, we detail how GameDesk, from ideation to implementation, explored how interactivity, simulation, and embodiment can support a variety of learning in the field of geoscience.

Based off the goals of the project, GameDesk created five games, including:

1. Five digital scenarios using the space simulator *Universe Sandbox* that cover **formation of the universe, galaxy, and planetary bodies**
2. A field game that covers the **principles of accretion**
3. A *Layers of the Earth* game using the SMALLab embodied learning technology that covers **layers of the earth** and **earth's surface**
4. A *Continental Drift* game using the Leap Motion Controller that covers **continental drift** and **earth's surface**
5. A *Plate Tectonics* game using the Leap Motion Controller that covers **plate tectonics, earthquakes, earth's surface, and land formation**

## Phase 1: Expert Roundtables: Content Domain Analysis and Task Modeling

During phase 1, GameDesk began ideating on how we could teach major earth and space sciences to students in engaging ways through high-quality interactive experiences. We were curious as to how embodied learning, simulations, and game mechanics could be utilized to teach challenging 6th to 9th grade geoscience topics, exploring how sound, music, kinesthetic learning, and storytelling could become fundamental features of the GeoScience games we were developing.

Through domain analysis, a method that determines and explores related concepts, properties, and abstractions of a given field, we identified eight possible topics for the game, including: 1) continental drift, 2) layers of the earth, 3) plate tectonics, 4) earthquakes, 5) earth's surface, 6) energy in the earth's system, 7) volcano creation, and 8) formation of the universe. For each topic, we identified learning outcomes, brainstormed game mechanics linked to the learning outcomes, and storyboarded how these concepts can be visualized.

## Phase 2: Domain to Game Mechanic Mapping

Although we began initial game mechanic mapping in our domain analysis, this phase focused on analyzing and identifying the different modalities that could accurately represent the eight geoscience topics. We investigated various technologies, such as digital simulators and motion tracking devices, and even outdoor field games. From our research, we identified the four different modalities that could be adopted to teach seven of the eight topics we explored in phase 1 (excluding energy in the earth's system). These four modalities are: 1) the physics-based simulator, *Universe Sandbox*, 2) an embodied outdoor field game, 3) the embodied learning technology, *SMALLab*, and 4) the *Leap Motion Controller*, a device that accurately tracks human hands and fingers.

## Phase 3: Prototype Design and Development

After identifying the four modalities in phase 2, we designed prototypes for each of them. In *Universe Sandbox*, we developed five different learning scenario challenges from the user-creation tool to showcase the principles of gravity, accretion, differentiation, and how the universe came to be. Since we were also interested in the transfer of knowledge of the same concepts across multiple modalities, we remixed a field game from the NASA Discovery Program wherein participants role-play as particles in space and move within a specified rule set (students must move toward closer objects, must move toward larger objects) to learn about gravity and accretion.

After developing games about the creation of the universe, we designed ones that focused on the creation of planets and land formations. We prototyped a *SMALLab* puzzle game called *Layers of the Earth* where players must work together to organize different materials (iron, mantle silicate, and crust) into appropriate zones.

We then decided to experiment with the *Leap Motion Controller* based on its practicality in a classroom (e.g., the device's small physical size, its highly accurate motion capture system, and low per unit cost). At this point, we prototyped a number of simulations around fluid dynamics (e.g., lava cooling and changing states as the user moves their hand higher).

## Phase 4: Science Content Revisions

Based on these initial prototypes, our curriculum team provided feedback to the design, ensuring that key terms were being used appropriately and game mechanics were intrinsically integrated into the content. Moreover, we took into consideration the feasibility of the modalities with respect to how easily they can be adopted in the classroom.

### **Phase 5: Game Development**

Design meetings with the curriculum team took place to make adjustments to the scenarios in *Universe Sandbox* and the rules of the accretion field game. At this time, the design team also began developing two games using the *Leap*, *Continental Drift* and *Plate Tectonics*, which explored continental drift theory, plate tectonics, and the formation of earthquakes, volcanoes, and valleys.

### **Phase 6: Small Group User Testing**

At this phase, all games we developed were ready for small group user testing. GameDesk held informal walk-in playtests with educators and students, gathering both user and observer feedback. All user testing was documented via video.

### **Phase 7: Data Gathering and Analysis**

Qualitative data from observers and users were recorded and reviewed by the design/curriculum team. Changes were made to the *Universe Sandbox* scenarios to better link to the learning outcomes (e.g., using every day objects in space to show that everything is subject to the laws of gravity) and to *Continental Drift* and *Plate Tectonics* to optimize motion capture of hand and finger orientation.

### **Phase 8: Larger Group Focus Testing**

The *Universe Sandbox* scenarios, accretion field game, *SmallLab Layers of the Earth*, and *Leap Continental Drift*, and *Leap Plate Tectonics* were tested at the PlayMaker School at New Roads, a private middle school, which served as a research and development site for GameDesk. Users were 36 6th grade students and two middle school teachers. Testing was documented via video.

### **Phase 9: Revisions**

Qualitative data from observers and users were recorded and reviewed by the design/curriculum team. Users' solutions in *Universe Sandbox* were saved and analyzed. We not only reviewed the content but also the modality of the experiences. Sample reflective questions include: What were students doing in the field game that they weren't doing in any of the other games? What do students' specific hand motions with the *Leap* tell us about their knowledge of the content? Revisions to content and gameplay were made.

### **Phase 10: Pilot Evaluation**

A third party evaluator conducted a pilot test for the *Active Accretion* field game, *Plate Tectonics*, and *Continental Drift* across seven different middle schools. *Universe Sandbox* and *SMALLab Layers of the Earth* were not evaluated because of the amount of time it'd take to install the software and properly run them. Pretests were administered to all students who completed them individually. Students played the game for one class period, and completed the posttest immediately after playing the game.

## Phase 11: Final Revision, Curriculum Development, & Media Production

Data from pilot testing, testing students' domain knowledge and attitudes about geoscience, informed final revisions. Based off pilot test results, user feedback, and recorded footage, GameDesk developed curricula/lesson plans for the *Universe Sandbox* scenarios, accretion field game, *Layers of the Earth*, *Continental Drift*, and *Plate Tectonics* that incorporated best teaching practices from our curriculum team and network of teachers. Each lesson plan consists of a 1) general description of the experience, 2) steps of the interactive experience, 3) its relation to learning, and 4) list of the learning outcomes.

## Phase 12: Dissemination

All curricula have been disseminated and are freely available through GameDesk's online portal, Educade. Furthermore, any games necessary to facilitate (e.g., the Plate Tectonics and Continental Drift games) are available for free on the GameDesk website.

Specific Objectives:

### Phase 1: Expert Roundtables and Content Domain Analysis and Task Modeling

In phase 1, our goal was to fully explore the domain of geoscience and how it has been taught to students in the past, ensuring thorough research of all related concepts, processes, and pedagogical approaches around the domain. The purpose for domain analysis was two-fold. First, it ensured we were doing our due diligence by identifying what essential topics in geoscience we wanted to cover (or not cover) and begin to understand how we wanted to teach them. Secondly, it forced us to set boundaries around the games we were creating, giving us a clearer academic and creative vision for the rest of the project.

*Phase 1 Deliverables: GeoScience Research Document*

### Phase 2: Domain to Game Mechanic Mapping

In phase 2, we researched and identified the various modalities (*Universe Sandbox*, *field game*, *SMALLab*, *Kinect*, *Leap Motion*) that could be used to teach geoscience concepts. This investigation allowed us to begin mapping game mechanics to the learning outcomes and consider how they would be represented in the modalities. From here, we determined the affordances of each modality and made informed decisions on which ones to adopt for the creation of our games.

*Phase 2 Deliverables: Identification of modalities, Initial game mechanic mapping*

### Phase 3: Prototype Design and Development

In this phase, we decided to begin building games with the modalities that would require the least amount of time to develop and were adequate enough for the experience we were creating; thus, we focused on creating scenarios in *Universe Sandbox* and an active accretion field game. We were also able to generate a prototype in *SMALLab* quite quickly in the programming language, UNITY.

With the *Leap Motion*, since the time to create prototypes for that device would take longer, we decided to create technical prototypes around systems/concepts we knew we wanted to explore (e.g., plate tectonics), also in UNITY.

*Phase 3 Deliverables: Universe Sandbox scenarios, SMALLab Layers of the Earth*

*prototype, Technical prototypes*

#### **Phase 4: Science Content Revisions & Phase 5: Game Development**

The content team reviewed the prototypes, serving as a “check point” to ensure that the learning outcomes we identified in the previous phases were being met, and that the overall vision of the project was intact. This review informed the next phase as more qualities of what we consider to be games (user interaction and choices) were being developed.

*Phases 4 & 5 Deliverables: Design Document with content feedback, Developed prototypes*

#### **Phase 6: Small Group User Testing & Phase 7: Data Gathering and Analysis**

As the prototypes evolved, we could now test them with users and see if they were operational. Individual users would engage with the games and talk aloud as our lead game designer, Joe France, made written observations. This allowed us to see where users would get stuck, what they liked/didn't like, bugs in the prototypes, and whether or not the geoscience content was intrinsically integrated to the game mechanics. Gathering this data provided us with valuable and quick feedback, making the games more playable and robust, both in gameplay and content, for the next phase. This phase also served as an initial test of our hypotheses that 1) we could represent geoscience concepts in engaging and accurate ways and 2) the experience would lead to deep conceptual and procedural understanding of the content.

*Phases 6 & 7 Deliverables: User feedback, Testing of hypotheses, Revised prototypes (now games)*

#### **Phase 8: Larger Group Focus Testing & Phase 9: Revisions**

Testing our games with a full class of students and teachers allowed us to see how the games would actually be implemented in a school setting with the intended users of the project. It was also important for us to see the social interaction students had with each other and the teachers. This informed phase 9 where we made revisions based on misconceptions students still had, the feasibility and merit of each of the modalities, and other gameplay issues that were still present. In this phase, we were also further able to test our main hypotheses at a larger scale.

*Phases 8 & 9 Deliverables: User feedback, Testing of hypotheses, Revised games*

***NOTE: Our work in phases 1-9 can be found in our two Design Documents, which we've attached under "Products" of this report.***

#### **Phase 10: Pilot Evaluation**

By phase 10, our games were at a stage where they were ready for evaluation from a third-party and for us to test our hypothesis that through embodied learning, simulations, and game-based learning, students would be able to develop deep conceptual knowledge of geoscience topics.

The evaluator pulled questions from the California Standards Test, the National Assessment of Educational Progress (NAEP), and the Geoscience Concept Inventory developed and validated by Prof. Julie Libarkin to assess college

student geoscience knowledge. These questions were relevant to three of the games: *Active Accretion* field game, *Continental Drift*, and *Plate Tectonics*.

*Phase 10 Deliverables: Third-party evaluation report*

**NOTE: An evaluation report of the results was generated and is attached to this report under "Products".**

### **Phase 11: Final Revision, Curriculum Development, & Media Production & Phase 12: Dissemination**

Final revisions were made to the games and offered for free to educators and students on our website. Moreover, through our user testing sessions in the previous phases, we were able to determine the best teaching practices for each of the games. We decided that developing curriculum around what we created was essential to the project, providing valuable insights of the GameDesk pedagogical model to our national audience. Moreover, since we had documented the user testing and pilot evaluation at the schools, we generated tutorial videos for the games and a video that showed the pedagogical approaches that guided the development of the geoscience games.

*Phases 11 & 12 Deliverables: Final version of all games, Full curriculum made available to public*

**NOTE: The full curriculum is attached to this report, and we've provided links to our videos. Both can be found under "Products". Links to our games and curriculum are listed in the field entry "How have the results been disseminated to communities of interest?"**

#### Significant Results:

#### **Phases 1-2**

##### *Different Modalities*

In our domain analysis, we hypothesized that adopting one modality (e.g., the *Kinect*) to teach the wide breadth of topics in geoscience was not feasible. We then began researching various modalities, both emergent (*Universe Sandbox*, *Leap Motion Controller*) and ones that have existed for years (field games and board games). For *Universe Sandbox*, since it had been released and was a powerful physics simulator that allowed for easy customization, we decided to begin our design prototypes around it.

- *Leap Motion*: During our first two phases, a significant result from our investigation of different modalities that we could use to teach geoscience concepts was discovering that the *Leap* was an ideal technology for our modules. Its small size and low per unit cost makes it feasible for a 1:1 device to student ratio. Compared to other motion tracking devices we researched, such as the *Kinect*, the *Leap* had a smaller field of capture which limited the amount of interference from other people. Moreover, its ability to capture a high degree of hand articulation and digital movement were conducive to the kinesthetic game mechanics that we mapped to the learning outcomes (e.g., grabbing, pulling apart and together). Further discussion with the manufacturers of *Leap* were also fruitful as we learned that the devices can and may be embedded into laptops and desktops easily, possibly making them a ubiquitous technology in classrooms.

#### **Phases 3-5**

After reviewing the original proposal, conducting domain analysis, and investigating modalities, we began developing large-scale conceptual prototypes that spanned from accretion (creation of the universe) to the layers of the earth. However, it was apparent that to cover such a wide span of topics, the game played like a movie, automatically moving from one phase to the next. Unfortunately, our first iteration minimized player interaction, which did not make for an engaging experience, since it asked players to give inputs with little feedback.

Three major design decisions were then made. First, we realized that our scope was too large. Telling the full story of geoscience in one game was not possible within the parameters of the grant. It reinforced our earlier hypothesis that it would require several modalities to teach geoscience concepts, and that some modalities would be better at teaching specific concepts. Secondly, in each of the games we were creating, we had to ensure that there were three design tenets: 1) a clearly defined goals, 2) obstacles to those goals, and 3) tools provided to the player to overcome those obstacles. Finally, we decided to develop games that focused on kinesthetic and embodied learning rather than being auditory-driven; we believed that to create a successful educational game around geoscience, movement was much easier to map to the content than music and audio.

### Phases 6-9

User testing provided key feedback to each of our games and our hypotheses (outlined in "What are the major goals of the project?"). We learned that the *Universe Sandbox* and *Active Accretion Field Game* required preparation and well-trained facilitators in order to run the games whereas *Continental Drift* and *Plate Tectonics* required less facilitation for users. By observing small and large group user testing, we were also able to extract best teaching practices, informing us of the best facilitation methods to produce the intended learning outcomes.

When reflecting on the game in relation to our hypotheses, we saw that while the games were engaging for students, we needed to integrate more of the educational content in them. We needed to clearly introduce and reinforce key terms and create better visualizations on the players' actions and how they were affecting what was happening in the game. For each game, we revised them so that we would cover fewer concepts but allow players to explore and do a deep-dive on those concepts.

**NOTE: Our work in phases 1-9 can be found in our two Design Documents, which we've attached under "Products" of this report.**

### Phase 10

From our pilot implementation and evaluation across seven middle schools, we learned that in the results for each of the three games—*Plate Tectonics*, *Continental Shift*, and *Active Accretion field game*—students made statistically significant gains, indicating that the games were successful in fostering the intended learning. The tests also included items tapping students' interest in geoscience and geoscience careers. Across the board, students' responses to these items also improved from pre to post. Finally, when time allowed, we asked students to rate the game experience, including whether the game taught them well, and whether their friends would like playing the game. Analyses revealed that students rating the games statistically significantly higher than the 'neutral' point on the scale, indicating positive response to the game experience. Furthermore,

students' responses also indicated increased interest and knowledge of related careers in the field of geoscience.

The student improvements from pre to post on these tests ranged from an average of 5% all the way up to an average of 25%. Results for the field accretion game showed improvements of almost 25%. When students played the plate tectonics game, they showed improvements of over 11% from pre to post. For the continental drift game, we saw improvements up to almost 25%

***NOTE: An evaluation report of the results was generated and is attached to this report under "Products".***

### **Phases 11 & 12**

Based off pilot test results, other user feedback, and recorded footage, GameDesk also developed curricula/lesson plans for each of the *Universe Sandbox* scenarios, accretion field game, *Layers of the Earth*, *Continental Drift*, and *Plate Tectonics* that incorporated best teaching practices from our curriculum team and network of experienced teachers. Each lesson plan consists of a (1) general description of the experience, (2) the series of steps of the interactive experience and (3) how it relates to learning, and a (4) list of the learning outcomes. We also realized that the reports of this project cannot be fully articulated with just the games we created and a few text documents; we wanted to tell a visual story of the project about how we did what we did and why. Thus, we generated tutorial videos for our games and informational videos about our process.

***NOTE: The full curriculum is attached to this report, and we've provided links to our videos. Both can be found under "Products". Links to our games and curriculum are listed in the field entry "How have the results been disseminated to communities of interest?"***

Key outcomes or Other achievements: Key outcomes and achievements have been addressed in "Significant results".

### **\* What opportunities for training and professional development has the project provided?**

The grant has provided several opportunities for training and professional development. These opportunities took place before and during the 2013-14 academic school year and they can be grouped into three types:

**1. GAMEDESK-LED PD:** Before the school year started, during the summer of 2013, GameDesk held and facilitated several face-to-face PD sessions to help prepare and plan for the field game on accretion. These sessions had several pedagogical objectives:

- To fully understand the topic at hand
- To determine desired learning outcomes
- To identify the main misconceptions students tend to have about this topic
- To role-play the activity among teachers in order to refine design and details of the implementation
- To practice facilitation techniques and core questions to be discussed with students after the activity

As is clear from the topics above, these sessions had the objective of preparing the teachers to do the activity in the most effective way. The goal of these sessions was not so much to transmit knowledge but to build a common understanding of what the students were expected to accomplish and the best way to facilitate their learning. These professional development sessions consisted of thorough and in-depth face to face conversations and embodied role-play experiences around the topics. Although the Principal Investigator led these discussions along with GameDesk field expert, Joe Wise, the learning goals, the misconceptions and the most effective ways to handle those misconceptions were the result of a collaborative effort of GameDesk personnel and the teachers.

These sessions were documented and the teachers had access to these documents to provide additional input, and to help get ready for the implementation day.

The day the activity was implemented, in the fall of 2013, several members of the PD team at GameDesk were present to help facilitate. Lucien Vattel, principal investigator, led the activity. GameDesk expert in the field, Joe Wise, led the discussion after the embodied experience, and the teachers contributed by helping the kids move through the field. Other GameDesk personnel assisted with the signs and with the logistics of implementing the activity in a park.

**2. COLLABORATIVE PD:** For some games (e.g., *Universe Sandbox* and *Layers of the Earth*), the GameDesk PD team held sessions attended by PlayMaker teachers in which participants brainstormed ideas for scenarios for each of the games, linked them to specific learning outcomes, discussed misconceptions that were addressed by these scenarios, and decided the order in which these activities should be presented to students. The GameDesk team proposed some early prototypes/ideas, but those were presented early enough so that there would be enough time to modify or even omit if the teachers didn't agree with the content or the activity itself.

The PD team followed this model (i.e., to present early unfinished prototypes) to foster among teachers a sense of ownership and commitment to the activity and the approach used. The approach proved effective as these sessions yielded several very good ideas, rich enhancements and modification that resulted in more engaging and appropriate learning experiences for students than the early prototypes GameDesk presented. Collegial collaboration was achieved, and was definitely the highlight of these sessions.

The teachers implemented the activities with their students and the GameDesk PD team attended and assisted in these sessions. GameDesk personnel documented the lesson plans on Educade.org.

**3. GAME-LED PD:** For some games (e.g., *Continental Drift* and *Plate Tectonics*), implemented toward the end of the school year, GameDesk developed the games with input received from the teachers throughout the year. During the spring, GameDesk PD team tested the games with groups of middle-school children in several schools throughout the city of Los Angeles.

In some of the schools, the GameDesk PD team held sessions to allow teachers to play and interact with the game in the same way as students do, with the objective of being more effective at facilitating learning. In other schools, the PD team implemented the game using two GameDesk expert facilitators, while the teachers observed the session and learned through observation. The two GameDesk expert facilitators engaged in a dialog with the teachers after the sessions to help them debrief and understand the session.

#### \* **How have the results been disseminated to communities of interest?**

All curriculum/lesson plans have been documented and are available for free on GameDesk's online portal, Educade. Educade is a website that offers a vast library of free, ready to use lesson plans integrated with 21st century teaching tools. Teachers, parents and students can find hundreds of apps, games, and hands-on activities that align to Common Core and Next Generation standards. Users can search for lesson plans by grade level, subject matter, and technology type, making it fast and easy to use. Educade has been custom built for educators today and provides high-tech, low-tech and no-tech solutions for a fully immersive learning experience. Furthermore, any games necessary to run the learning experiences (e.g. the *Plate Tectonics* and *Continental Drift* games) are available for free on the GameDesk website: <http://gamedesk.org/project/geomoto/>

GameDesk is also in the process of producing a white paper about the state of embodied and game-based learning in science topics, and disseminating the promising results of our evaluation report to the general public (we have attached an early version of the report under "Products").

#### **Educade Links:**

**Universe Sandbox Teaching Tool Page:** [http://www.educade.org/teaching\\_tools/universe-sandbox-1](http://www.educade.org/teaching_tools/universe-sandbox-1)

**Universe Sandbox Module 1 - Accretion, Differentiation, and Density:**  
[http://www.educade.org/lesson\\_plans/534853db39c6eb08b3000001](http://www.educade.org/lesson_plans/534853db39c6eb08b3000001)

**Universe Sandbox Module 2 - Laws of Gravity with Bowling Ball &****Teapot:** [http://www.educade.org/lesson\\_plans/laws-of-gravity-bowling-ball-and-teapot-with-universe-sandbox](http://www.educade.org/lesson_plans/laws-of-gravity-bowling-ball-and-teapot-with-universe-sandbox)**Universe Sandbox Module 3 - Planet X - Adding an Object to an Orbital****System:** [http://www.educade.org/lesson\\_plans/planet-x-adding-an-object-to-a-working-orbital-system-with-universe-sandbox](http://www.educade.org/lesson_plans/planet-x-adding-an-object-to-a-working-orbital-system-with-universe-sandbox)**Universe Sandbox Module 4 & 5 - Save the Earth and Explore Orbital****Patterns:** [http://www.educade.org/lesson\\_plans/explore-orbital-patterns-by-saving-the-earth-with-universe-sandbox](http://www.educade.org/lesson_plans/explore-orbital-patterns-by-saving-the-earth-with-universe-sandbox)**SMALLab Layers of the Earth:** [http://www.educade.org/lesson\\_plans/53ebe25639c6ebfba4000001](http://www.educade.org/lesson_plans/53ebe25639c6ebfba4000001)**Active Accretion Field Game:** [http://www.educade.org/teaching\\_tools/active-accretion](http://www.educade.org/teaching_tools/active-accretion)**Plate Tectonics & Continental Drift Teaching Tool Page:** [http://www.educade.org/teaching\\_tools/geoscience-continental-drift-and-plate-tectonics](http://www.educade.org/teaching_tools/geoscience-continental-drift-and-plate-tectonics)**Plate Tectonics Lesson Plan:** [http://www.educade.org/lesson\\_plans/plate-tectonics](http://www.educade.org/lesson_plans/plate-tectonics)**Continental Drift Lesson Plan:** [http://www.educade.org/lesson\\_plans/continental-drift](http://www.educade.org/lesson_plans/continental-drift)

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## Products

### Books

### Book Chapters

### Conference Papers and Presentations

### Inventions

### Journals

### Licenses

### Other Products

*Audio or Video Products.*

We created a video that details the goals of the project and summarizes our design process and findings from pilot implementation. The video can be found here: <http://vimeo.com/101570313>

We've also created individual videos documenting the user testing of our modules.

*Layers of the Earth:* <http://vimeo.com/97530164>

*Continental Drift:* <http://vimeo.com/97526912>

*Plate Tectonics:* <http://vimeo.com/97527436>

*Active Accretion Field Game/Universe Sandbox/Layers of the Earth:* <http://vimeo.com/87731892>

*Educational aids or Curricula.*

Based off pilot test results, other user feedback, and recorded footage, GameDesk also developed curricula/lesson plans for the games we developed with the grant. This includes each of the *Universe Sandbox* scenarios, *Active Accretion* field game, *Layers of the Earth*, *Continental Drift*, and *Plate Tectonics* where we incorporated best teaching practices from our curriculum team and network of experienced teachers.

Attached to this report is a document (titled GEOMOTO TRANSMEDIA GAMES) that describes five different learning experiences developed to explore how interactivity, simulation, game mechanics, and embodiment support a variety

of learning outcomes. Each section provides a (1) general description of the experience, (2) a series of steps of the interactive experience and (3) how it relates to learning, and (4) a list of the learning outcomes.

### *Design Document.*

Attached to this report are two document (titled GeoScience Design Document - Part 1 & 2) which served as a design guidebook of the concepts in geoscience we wanted to cover with proposed learning outcomes, game mechanics, and visual designs of the project.

### *Third Party Evaluation Report.*

Attached to this report is a document from a third party who conducted an evaluation of three of our modules independently: *Plate Tectonics*, *Continental Drift* and *Active Accretion* field game.

## Other Publications

### Patents

### Technologies or Techniques

Targeting California Science State Standards for earth science and geoscience, *Continental Drift* and *Plate Tectonics* utilize Leap Motion technology to teach players about those topics. Players will challenge their creative problem solving skills through sophisticated game play and have their learning reinforced through this multi-sensory teaching tool. These modules are designed to bring misconceptions about traditionally challenging geoscience concepts to the surface, and includes opportunities for students to correct their understanding through experience and interaction.

Products are available at the GameDesk website: <http://gamedesk.org/project/geomoto/>

Furthermore, we've created video tutorials for *Plate Tectonics* and *Contentinal Drift*.

*Continental Drift* tutorial video: <http://vimeo.com/98674900>

*Plate Tectonics* tutorial video: <http://vimeo.com/98674901>

## Thesis/Dissertations

### Websites

### Supporting Files

Filename	Description	Uploaded By	Uploaded On
GEOMOTOTRANSMEDIAGAMES.pdf	This file is curriculum that describes five different learning experiences developed for exploring how interactivity, simulation, game mechanics, and embodiment support a variety of learning outcomes.	Lucien Vattel	10/22/2014
GeoScience Design Document - Part 1.pdf	Part 1 of the design guidebook, detailing the concepts in geoscience we wanted to cover with proposed learning outcomes, game mechanics, and visual designs of the project.	Lucien Vattel	10/23/2014
GeoScience Design Document - Part 2.pdf	Part 2 of the design guidebook, detailing the concepts in geoscience we wanted to	Lucien Vattel	10/23/2014

cover with proposed learning outcomes, game mechanics, and visual designs of the project.

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Geoscience Evaluation Report.pdf	This is a document from a third party who conducted an evaluation of three of our modules independently: Plate Tectonics, Continental Drift and Active Accretion field game.	Lucien Vattel	10/23/2014
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## Participants/Organizations

### What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Vattel, Lucien	PD/PI	12
Riconscente, Michelle	Faculty	3
Hidalgo, Paula	Other Professional	5
Lam, Mylo	Other Professional	2
Nye, Bill	Consultant	2
Clausen, Matt	Other	7
France, Joe	Other	4

### Full details of individuals who have worked on the project:

#### Lucien Vattel

**Email:** [lucienvattel@gamedesk.org](mailto:lucienvattel@gamedesk.org)

**Most Senior Project Role:** PD/PI

**Nearest Person Month Worked:** 12

**Contribution to the Project:** Principal Investigator and lead of GameDesk team.

**Funding Support:** NSF budgeted

**International Collaboration:** No

**International Travel:** No

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#### Michelle Riconscente

**Email:** [designs4learning@gmail.com](mailto:designs4learning@gmail.com)

**Most Senior Project Role:** Faculty

**Nearest Person Month Worked:** 3

**Contribution to the Project:** Assessment design and implementation.

**Funding Support:** NSF budgeted

**International Collaboration:** No

**International Travel:** No

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**Paula Hidalgo**

**Email:** paulah@gamedesk.org

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 5

**Contribution to the Project:** Coordinated pilot implementations, contributed to research design, and development of the modules.

**Funding Support:** NSF budgeted

**International Collaboration:** No

**International Travel:** No

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**Mylo Lam**

**Email:** mylol@gamedesk.org

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 2

**Contribution to the Project:** Coordinated and documented artifacts of the project and wrote final report.

**Funding Support:** NSF budgeted

**International Collaboration:** No

**International Travel:** No

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**Bill Nye**

**Email:** billn@planetary.org

**Most Senior Project Role:** Consultant

**Nearest Person Month Worked:** 2

**Contribution to the Project:** Content expertise and review.

**Funding Support:** NAS Funded

**International Collaboration:** No

**International Travel:** No

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**Matt Clausen**

**Email:** mattc@gamedesk.org

**Most Senior Project Role:** Other

**Nearest Person Month Worked:** 7

**Contribution to the Project:** Led the design of three of the games.

**Funding Support:** NSF budgeted

**International Collaboration:** No

**International Travel:** No

**Joe France**

**Email:** Josephf@gamedesk.org

**Most Senior Project Role:** Other

**Nearest Person Month Worked:** 4

**Contribution to the Project:** Designed and developed two of the modules.

**Funding Support:** NSF budgeted

**International Collaboration:** No

**International Travel:** No

**What other organizations have been involved as partners?**

<b>Name</b>	<b>Type of Partner Organization</b>	<b>Location</b>
CalTech	Academic Institution	CA, USA
LucasArts	Industrial or Commercial Firms	San Francisco, CA
National Academy of Sciences	Other Nonprofits	USA
Planetary Society	Other Nonprofits	Pasadena, CA, USA
PlayMaker School	School or School Systems	Los Angeles

**Full details of organizations that have been involved as partners:**

**CalTech**

**Organization Type:** Academic Institution

**Organization Location:** CA, USA

**Partner's Contribution to the Project:**

Collaborative Research

**More Detail on Partner and Contribution:** Scientists from the CalTech Plate Tectonics Laboratory contributed content expertise to the project, through in-person working design sessions at the GameDesk offices, as well as through email and phone exchanges.

**LucasArts**

**Organization Type:** Industrial or Commercial Firms

**Organization Location:** San Francisco, CA

**Partner's Contribution to the Project:**

Collaborative Research

**More Detail on Partner and Contribution:** Game designers from LucasArts contributed to the game design process.

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## National Academy of Sciences

**Organization Type:** Other Nonprofits

**Organization Location:** USA

**Partner's Contribution to the Project:**

Financial support

**More Detail on Partner and Contribution:** Provided additional financial support for game development and artists.

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## Planetary Society

**Organization Type:** Other Nonprofits

**Organization Location:** Pasadena, CA, USA

**Partner's Contribution to the Project:**

Collaborative Research

**More Detail on Partner and Contribution:** Bill Nye ("the Science Guy") from the Planetary Society contributed content and instructional expertise. Bill took part in multiple working sessions at the GameDesk offices, and also provided input via email and phone exchanges.

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## PlayMaker School

**Organization Type:** School or School Systems

**Organization Location:** Los Angeles

**Partner's Contribution to the Project:**

In-Kind Support

Facilities

Collaborative Research

Personnel Exchanges

**More Detail on Partner and Contribution:** Major host of all early use case in-classroom activists. Teacher and staff budget were not from this grant.

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## Have other collaborators or contacts been involved? No

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## Impacts

### What is the impact on the development of the principal discipline(s) of the project?

This project has made an impact on the **pedagogical methods** that can be used to teach Earth and Space Sciences.

1. In exploring the use of *Leap Motion Controller*, GameDesk has opened up rich possibilities for the use of this device to help students understand complex Earth and Science topics (as well as other topics in science and in other content areas).
2. The creation of scenarios for the Universe Sandbox game allowed GameDesk to explore possibilities of using games that have been developed for more mature audiences, by adapting them to a younger audience. The way

we did it in this particular case was through the creation of scenarios that limited the amount of data, interactivity, topics and even sections of the game. By creating these scenarios, we focused our students in on specific topics which allowed us to achieve the learning goals. We suggest that we can extrapolate from this experience to other games since there are lots of games that might be too complex for school children of certain ages, but can be made appropriate for their ages with a few modifications (like we did when we created the scenarios).

3. The use of embodied learning activities (like we did with the field-game *Active Accretion*) demonstrated that using the whole body as a way to represent either parts or aspects of a topic can help children better understand the topic, better comprehend the relationships and better remember it. We hold that embodied experiences can be used in many areas of knowledge (not only in Earth and Space sciences, and not only in science).
4. Furthermore, by having multiple modalities that teach similar concepts (e.g., *Active Accretion* field game and the *Universe Sandbox* scenarios), we believe that we are promoting the belief that students have a multitude of ways they learn best, be it visually, auditory, or even kinesthetically. By exposing them to the same concepts across various modalities, students can better retain the knowledge, skills, and abilities that are essential to the topic, providing invaluable information to themselves, educators, researchers, and parents about how they learn best.

### **What is the impact on other disciplines?**

This project also made a contribution to many other areas beyond Earth and Space sciences.

1. We hope that the use of the *Leap Motion Controller* will spread as the device becomes more stable and as the company manages to scale up and lower the price.
2. We believe that we are likely to make an impact in the use of other games (conceived as educational games and otherwise) and that we have helped deepen the understanding of how games can be used.
3. We also believe that we are likely to make an impact on how embodied learning experiences are used in schools to teach various topics (not only Earth and Space science topics, and not only topics that are traditionally thought of as conducive to using this approach).

### **What is the impact on the development of human resources?**

Nothing to report.

### **What is the impact on physical resources that form infrastructure?**

Nothing to report.

### **What is the impact on institutional resources that form infrastructure?**

Nothing to report.

### **What is the impact on information resources that form infrastructure?**

Nothing to report.

### **What is the impact on technology transfer?**

Our main contribution to technology transfer in this project is showcasing the viability of the *Leap Motion Controller* for classroom and lab environments. As we've detailed in our "Accomplishments", the many affordances of the *Leap* make it easy to procure, deploy, and implement. Discussions with the *Leap* manufacturer as to how we can continue the development of educational games and resources for the device have been promising as we seek to promote embodied learning experiences for learners of all ages.

Our work in *Universe Sandbox* also highlights how seemingly complex but content-rich tools can be adopted for a younger audience when properly facilitated and with a comprehensive understanding of the tool's possibilities. The creation of these scenarios and accompanied lesson plans should promote further discussions and strategies of how powerful tools like *Universe Sandbox* can be effectively used to teach traditionally challenging concepts.

### **What is the impact on society beyond science and technology?**

Nothing to report.

## Changes/Problems

### **Changes in approach and reason for change**

Nothing to report.

### **Actual or Anticipated problems or delays and actions or plans to resolve them**

Nothing to report.

### **Changes that have a significant impact on expenditures**

Nothing to report.

### **Significant changes in use or care of human subjects**

Nothing to report.

### **Significant changes in use or care of vertebrate animals**

Nothing to report.

### **Significant changes in use or care of biohazards**

Nothing to report.

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## Special Requirements

### **Responses to any special reporting requirements specified in the award terms and conditions, as well as any award specific reporting requirements.**

Nothing to report.