NASA eEducation
Research and Development Implementation Guide

Prepared for NASA eEducation

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Executive Summary

The eEducation program is the home of the research and development branch of the Office of Education. As NASA strives to fulfill the Vision for Space Exploration, the Agency must join in the efforts to expand the number of students drawn to fields of study in Science, Technology, Engineering and Mathematics (STEM). The nation must mount greater efforts to overcome the anticipated shortages of STEM workers if it is to remain competitive in technical endeavors. NASA recognizes that it is imperative to expand the resource of future STEM workers by increasing the numbers of students studying and graduating in STEM areas. It is the goal of eEducation to research and develop the innovative technologies and revolutionary uses of established technologies to support all the divisions of NASA's Office of Education and Mission Directorates in order to build an infrastructure to engage American students in ways that are familiar and meaningful to them. This will efficiently facilitate their entry and retention in STEM fields of study.

Marc Prensky coined the phrase *digital natives* to identify the generations born since the personal computer and digital technology have become common household tools. More media savvy and skilled at multi-tasking than their parents, *digital natives* find many traditional and analog approaches to learning, or working slow, under-powered and illogical. It is similar to the way adults from the previous generation would feel about being pushed into a world where the majority of people still used the abacus or scrap paper to do math after the advent of the pocket calculator. To attract *digital natives* into STEM fields of study NASA, and concerned entities, will need to reach those *digital natives* where they live: literally, in their digital world. eEducation is researching applications and effectiveness of podcasting, digital television and computer games as educational tools. A significant first step in the development of a broader synthetic environment is the creation of a commercial quality, Massively Multiplayer Online Game (MMOG) based on NASA's vision and mission. Since virtually all students have computer and video game experience, the NASA MMOG will be a familiar, easily accessible gateway to a NASA synthetic environment. NASA is in a position to put into place the cyberstructure to allow the United States to become an. science-faring civilization. eEducation will enable the development of a synthetic environment based on game technology with accurate physics rendering: a *siberspace* where students and teachers, engineers and scientists, researchers and designers, can immerse themselves in accurate representations of NASA facilities, missions, careers and data.

NASA's pioneering efforts in this area will be guided by the Federation of American Scientists' research roadmaps. Academic, governmental and industry stakeholders can play a significant role in expanding the efficiency of the synthetic environment. NASA's Mission Directorates have vital role to play in supplying the content and themes that will give the *siberspace* meaning and relevance. The eEducation projects will provide the initial research and development necessary to establish a NASA synthetic world, integrate with existing electronic educational assets and ensure the development of authoring tools to allow the NASA's Elementary and Secondary, Higher and Informal Education divisions, as well at the Mission Directorates, to enhance the NASA-based synthetic environment and MMOG.

The Challenge for NASA

NASA faces the prospect of having an insufficiency of trained professionals in science, technology, engineering and mathematics (STEM) fields to fulfill the Vision for Space Exploration. The shortage of a highly skilled technical workforce is not a NASA-unique problem, but one faced by the Nation as a whole (NSF: *Rising Above the Gathering Storm*, 2005). It is shortsighted to think that NASA should expect to attract a greater proportion of a shrinking pool of new STEM graduates in the near future. The best course for NASA and the Nation is to expand the overall number of STEM graduates. Attracting more STEM graduates requires either guiding more students onto paths that lead to STEM degrees, increasing the percentage of students on those pathways that complete STEM degrees, or both. Those three possible approaches suggest three target populations for STEM enhancement:

- Students who have the capability to pursue academic careers in STEM but do not do so.
- Students who have the capability to pursue academic careers in STEM and do so, but withdraw from STEM programs.
- The teachers and influence agents who impact either STEM education directly or who influence academic career decisions.

NASA lacks the resources and the mandate to directly alter the fabric of the American education system, thus adopts the charge in the *2006 NASA Strategic Coordination Framework* to increase the pool of students who graduate in STEM degree fields. To meet that charge, NASA Education must strategically use resources with the greatest potential to impact the target populations.

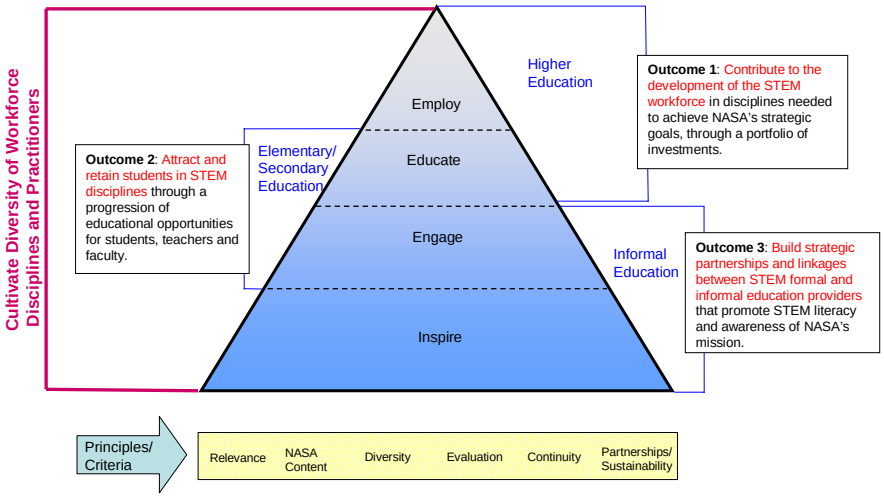
NASA eEducation: Targeted Outcomes and Categories of Involvement

NASA contributes to our Nation's efforts to achieve excellence in science, technology, engineering, and mathematics (STEM) education. Three outcomes serve to align all Agency education investments. eEducation has been identified as a cross-cutting function that supports all three of the Agency's education outcomes and is expected to target specific audiences with appropriate levels of involvement to cut across all four levels of the Education Framework.

eEducation investments are expected to map to at least one of the three NASA Education outcomes as part of annual performance and to contribute to the appropriate annual performance goals (APGs).

> Outcome 1: Contribute to the development of the STEM workforce in disciplines needed to achieve NASA's strategic goals, through a portfolio of investments.
>
> Outcome 2: Attract and retain students in STEM disciplines through a progression of educational opportunities for students, teachers, and faculty.
>
> Outcome 3: Build strategic partnerships and linkages between STEM formal and informal education providers that promote STEM literacy and awareness of NASA's mission.

eEducation shall develop an infrastructure and deploy research-based technology applications, products, and services that enhance the educational process for formal and informal education. Serving to provide guidance and continuity across the eEducation Program is this Roadmap and Research Strategy intended to embrace other NASA and external entities into this effort.



NASA needs to focus on its unique assets to maximize the impact of educational efforts. What sets NASA apart from the Department of Education is technology (Remarks by Angela Diaz to the Johnson Space Center Office of Education January 17, 2006). eEducation serves as the research and development incubator to support the development of innovative technology tools to enhance formal and informal STEM education.

An Answer to the Challenge: More than a Game - A Synthetic World

Among the goals of eEducation is to meet the President's Management Agenda to provide citizen-centric services related to NASA Education efforts. By the end of 2004, experts on synthetic worlds estimated that 10-20 million Americans were exploring, playing and even working in synthetic worlds (Castronova, 2005). Interest and involvement in digital worlds is expected to increase exponentially with the spread of broadband internet access. NASA is already in the process of digitizing all of its educational materials. The time is now to begin to make the infrastructure digital as well: to build NASA's cyberstructure. This cyberstructure should be a synthetic world where the rules of physics and the principles of engineering can be studied and understood through experiments that cannot be conducted on Earth. The immersive environment should be powerful enough to convey a sense of being there.

Examples of Synthetic Worlds

Castronova (2005) argues that the dawn of the age of immersive synthetic worlds is here. He calls the 3D-rendered graphics of high-end computer and video games "practical

virtual reality." The difference between immersion in a synthetic world and text message or a teleconference is a psychological one. The use of personal representation ("avatars" in technical literature, but colloquially known as "characters" or "toons" or just "me" by game players) inside the game worlds gives a deep level of personal engagement. The player of *EverQuest*™ is immersed in cyberspace.

Second Life™ is an example of a synthetic world that is not a game. Users create avatars and experience the environment just as they would in a game, but there are no established goals or objectives for the avatars to accomplish. As a game, this design would seem rather boring. However, more than 100,000 users have *Second Life*™ accounts which they use regularly. The attraction for *Second Life*™ users is the synthetic world itself and the chance to interact with other users. Built into the code of *Second Life*™ are tools that allow users to build objects inside the synthetic environment. This synthetic world is not simply a 3D chat room. The persistence of the environment and the ability for users to affect it, have a significant impact on the nature of the space. Users in *Second Life*™ earn currency called Linden Bucks which they can trade with other users for goods and services. It is also possible to buy Linden Bucks with real currency to finance avatar-based activities in the *Second Life*™. The users of *Second Life*™ have developed online support groups, created social clubs, designed games to play inside the synthetic world, and open and operate in-world businesses. Some of them have also been teaching real world courses inside the synthetic world. Teachers and students interact through avatars. One physics professor at Northwestern University uses Second Life™ as a virtual meeting space rather that text-based systems like BlackBoard™ (Border, 2005). An instructor at the University of Illinois's College of Education is conducting her entire course on "Cognitive Science in Teaching and Learning" in Second Life™. Some instructors create materials to be studied and experimented upon in *Second Life*™, while others make the time in *Second Life*™ the object of their lessons in the social sciences or game design.

Massively multiplayer online games (MMOG) have characteristics that set them apart from other games. They are shared spaces where hundreds, thousands and even millions of players can experience the same game. They are persistent and evolving online environments. For example, with a stand-alone game, the game environment turns on and off at the user's whim and is essentially loaded with all of its potential states when it is shipped from the factory. If there is a sequel, the new game comes with a brand new, though probably familiar, game environment. MMOGs, in contrast, run continuously. Actions by players can alter the game world and the game creators can change features of the world through expansions or patches. The persistent and evolving nature of MMOGs makes them more like the real world and less like the static, intermittent nature of stand-alone games. The game setting in MMOGs, is thus a synthetic world, while the game setting of a stand-alone game is not.

NASA Applications of Synthetic Worlds

A game-quality synthetic world will be a vital element of NASA's cyberstructure. The synthetic world will be a collaborative work and meeting space of a kind familiar to increasing numbers of Americans. Games and challenges in the synthetic environment

will engage students in a way that is both familiar and comfortable for them. In turn, success in the games will build increased student awareness of STEM fields. The synthetic environment will allow immersive career exploration opportunities in a much deeper way than reading alone would permit and at a fraction of the time and cost of an internship. If the average internship costs $30,000 and the annual cost of a full-scale NASA MMOG is $3 million, this means 100,000 or more players could virtually experience NASA in a deep meaningful way for what it costs to give real experiences to 1000 students. While NASA internships would still offer unique experiences, a much wider array of students will be able to experience NASA through a synthetic environment. The tools are at hand to expand the pool of students who experience NASA directly from a select few to an egalitarian plurality.

NASA personnel will be able to use the environment to communicate and collaborate in ways that are more personally engaging than either tele- or videoconferences. The immersive nature of the synthetic world with its practical virtual reality is psychologically more engaging than other forms of remote communication (Castronova, 2005). Emotional engagement can be a key factor in both memory and learning. Basic tools for collaborating in game-like environments have already been developed and are starting to be implemented in portions of NASA. An information technology group at Kennedy Space Center has worked with Valador, Inc, to create a prototype of such an interface. Valador's first experiments in this arena developed a modification to the Unreal Tournament game to create an immersive online meeting environment. Though built as a game mod, the final product is not a game. It is simply a space where users can interact through avatars to meet and exchange information in high fidelity renderings of parts of Kennedy Space Center and the surface of Mars. Communications tools like these are available to young people in their recreation. They should not have to ratchet down the power of their tools when they come to work for NASA.

NASA Administrator Griffin has said that his goal for NASA is to put into place the engineering infrastructure to allow the United States to become a space-faring civilization (address at Goddard Space Flight Center, October 2005). He means to build the platforms to allow exploration and research anywhere in the solar system with NASA primarily focused on the engineering and university partners primarily focused on the science. eEducation should take a similar role in regard to cyberspace.

The Internet remains largely a non-immersive communications tool. Truly immersive, digital environments are still only adjuncts to the greater network. Instead of one immersive, parallel world, there are many. Academics and game designers see powerful potential to harness the technology of synthetic worlds for learning. NASA needs to put in place the cyberstructure to allow the United States to become an immersive science-faring civilization. eEducation needs to enable the development of a synthetic environment based on game technology with accurate physics rendering: a *sciberspace* where students and teachers, engineers and scientists, researchers and designers can immerse themselves in accurate representations of NASA facilities, missions, careers, and data.

Games and challenges will need to be designed to attract student interest in NASA and STEM careers. Developer toolkits will need to be available to allow expansion and enhancement of the synthetic world. eEducation can build the cyberstructure to support a synthetic environment and the authoring tools to allow Mission Directorates, Office of Education divisions and external partner add to the environment. Curricular support and lesson guides will be required to support formal learning. In-world assessment and tracking tools will have to be designed both to support educational goals and to protect the integrity of individual avatars.

This proposed synthetic world has potential to support all manner of STEM endeavors and should be an asset to other Federal agencies and academic institutions. NASA's role is to insure the fidelity of the technology and the accuracy of rendering of engineering and science in *sciberspace*. No other agency has the unique combination of technology, science, and engineering mastery and experience to fill that role. With a charter to support learning with technology tools, eEducation is uniquely positioned within NASA to coordinate this effort.

Roles for eEducation Components

eEducation Unit	FY07	3 years	5 years	10 years
LTP Focus Area: *educate* and *employ*	Solicit for a NASA game to be the foundation of a synthetic world Build partnerships to leverage synthetic world development Support the development of a prototype educational MMOG	Release a full scale synthetic world containing NASA games and challenges Release an assistive interface to enable blind users to experience the synthetic world	Reach 10 million registered users and be recognized as a valued learning tool NASA missions rely on the synthetic world as a primary element in their education and outreach plans	Millions of people attend the return to the moon inside the NASA synthetic world and the astronauts acknowledge their virtual presence Be as recognized a learning tool by the graduates of 2020 as Oregon Trail and SimCity were in by graduates in 2000.
COTF Focus Area: *educate* and *engage*	Research and select or design appropriate assessment tools for use in an MMOG and other games and synthetic	Support the development of in-world learning tools through the VDC Assess learning	Assess learning and academic career impact of the NASA synthetic world Publish on the best learning	

	environments.	in the synthetic world in formal and informal education settings	practices for use with an MMOG environment	
NETS Focus Area: *inspire* and *engage*	Recommend options for accessing Web-based learning services from the Education sections of the Portal (including low-bandwidth, mobile devices and assistive technologies) Establish commonality among education program Web sites. This initiative would require researching "kid-directed" NASA activities for older (middle and high school) students.	Develop a Kids Club set of activities in the synthetic environment Establish alternate media outlets from the synthetic world to the real world (podcast, reporting)	Guide 'graduating' Kids Club members into other learning opportunities in the synthetic environment.	
CORE Focus Area: *educate* and *engage*	Repurposing existing NASA educational materials by meta-tagging and digitizing these materials to be delivered electronically and adding on-line ordering to service our	Offers the entire library of NASA educational materials through an outpost in the synthetic world complete with online sampling of all materials	CORE-bots interact with users to guide them to the best NASA educational materials for the users' needs	

	customers in the synthetic world.			
eERC Focus Area: *educate* and *engage*	Develop a series of blended training components based on existing NASA educational materials	Offers completely immersive training within the synthetic world	Be cited by name by school districts and schools of education valued for professional development	
DLN Focus Area: *educate* and *engage*	While continuing to provide synchronous interactive sessions between NASA Centers and classrooms, integrate asynchronous technologies as pre and post event activities.	Using the synthetic world for pre and post event activities, create hybrid real-time events embedded in an immersive environment.	Fully implement the hybrid model in a significant number of DLN events ensuring that users interact with real NASA experts while benefiting from the unique learning opportunities afforded by the synthetic world.	

Research Plan

NASA is not alone in its interest in MMOGs as learning environments. Interest in MMOGs has been discussed at multiple conferences and meetings including: Serious Games Summit, 2005 and 2006; the Federation of American Scientists' Summit on Educational Games, 2005; and National Academies Game-based Learning Workshop, 2005. The National Science Foundation and National Institutes of Health have funded development of educational games. To date, however, there has been no coherent strategy employed to guide the development and assessment of an educational MMOG. In 2003, the Learning Federation, an arm of the Federation of American Scientists supported by a grant from the National Science Foundation, released a series of research and development road maps for learning science and technology that focused on the use of games and simulations. NASA eEducation will follow the research strategy developed by the Learning Federation in an effort to build upon a collaborative framework. Subsequently the Federation of American Scientists convened a national Summit on Educational Games to explore the potential of educational games to address our nation's education and training needs. Among the findings and recommendations to come out of the Federation of American Scientists' *Summit on Education Games* was the conclusion that a robust program of research and experiments on educational games needs to be undertaken with Federal agency leadership (FAS, 2006). In connection with the summit,

a research and development roadmap was drafted to raise awareness of key research challenges, and to encourage dialogue and partnerships in carrying out an R&D agenda that supports the development and design of educational games. The full report, R&D Challenges in Designing Games and Simulations for Learning, is available at: http://www.fas.org/gamesummit/. Among the findings and recommendations to come out of the Federation of American Scientists' *Summit on Education Games* was the conclusion that a robust program of research and experiments on educational games needs to be undertaken with Federal agency leadership The recommendations also include a list of research and development challenges that developers of educational games should consider.

With funding from NASA the Federation of American Scientists developed a roadmap focused on R&D challenges for the design of MMOGs that built on the games and simulation roadmap and outlined specific R&D targeted to massively multiplayer online games in the eEducation research plan. Study of existing MMOG for a better understanding of how learning takes place in synthetic worlds will be an essential step in informing the development of a NASA-based synthetic world. By developing an MMOG that addresses these specific research questions identified in an advance, research consideration can be factored into development. Following the Learning Federation research plan also provides strong opportunities to establish a collaborative research base between government agencies, private foundations, universities, educational institutions and commercial entities. The Federation of American Scientists has collaborated with NASA to develop as strategic research roadmap to guide NASA eEducation and partners.

Stakeholder Involvement

Within NASA, eEducation needs to involve the Mission Directorates in the development of a synthetic educational environment. The Mission Directorates are the repositories of the data and missions that will be the essential focus of a NASA MMOG. A true NASA *ciberspace* will need to be populated with Mission Directorate content. Development and expansion of the game space will be guided by NASA's missions. The development of the synthetic environment needs to build in hooks from content areas in support of missions. As much as possible, the shape and content of the game needs to be directed by the Vision for Space Exploration.

Externally, there is a public good and large social return to the Nation associated with improving STEM education and workforce training. NASA is in a position to take a leadership role collaborating with the Department of Education, Department of Defense, the National Science Foundation and other agencies in implementing a research and development agenda that will encourage partnerships between governments, academia, industry and schools to develop educational games.

Federal research and development are vital to fulfilling the potential of educational games. The commercial game industry lacks the motivation and desire to fund the basic research necessary to underpin successful educational games. Federal investment is needed to overcome this barrier and to foster public-private partnerships to understand

and develop games to enhance STEM education. Game developers have the experience and talent needed to design successful games. NASA and other agencies have the mandate to enhance STEM education and the science and engineering data to do so.

eEducation Unit Dynamics

The various eEducation units need to work with a significant degree of collaboration in order to maximize use of resources and eliminate redundant research and development. Each unit needs to be aware of the goals and progress of the other units and maintain a strong awareness of areas of linkage and mutual support. This close working relationship can be enhanced through the establishment of an annual eEducation meeting and monthly eEducation working group (EEWG) teleconferences. Establishment of common online communication tools including a repository for documents and asynchronous discussion tools will further enhance awareness and collaboration. Once a synthetic environment is sufficiently complete, meetings and collaborations will be conducted there. Development and deployment of a synthetic environment cyberstructure is a significant undertaking that will require coordinated engagement of all of the eEducation units as well as the Office of Education divisions, Mission Directorates and external partners. This sciberspace will not be only tool in the eEducation portfolio, but rather an overarching framework that pulls the others together. Such technologies as digital TV delivery, the Web, pods and podcasting, cell phones will remain part of the eEducation toolbox.

Programmatic Push-Pull

eEducation is fundamentally a cross-cutting program that serves to support and enhance other Office of Education and Mission Directorate programs through innovated uses of technology. Development of a synthetic world will provide the cyberstructure that will allow students to easily locate and apply to NASA's many educational programs. In-world hooks and pointers will direct interested students to programs appropriate to their interests and aptitudes. The synthetic world itself will provide source of continuity to lead program alumnae onto appropriate next steps. The existence of a permanent avatar in the NASA synthetic world will act as a beacon to draw students to STEM careers and to further NASA experiences. The student that first learns about the NASA MMOG through the NASA Kids' Club of the NASA display at their local science center will be likely to be drawn to other NASA opportunities after facing the challenges of the game. With links to program descriptions and applications built into the synthetic environment, that student will be able to easily locate the NASA education opportunities that match their interests. Experience in the NASA synthetic environment will better prepare the students to succeed in the other NASA programs.

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