NASA Learning Technologies

Experiential Platform – *ExP*
Overview and Requirements Specification

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Authors: NASA Ames Learning Technologies Staff

Reviewers

Name	Function	Comments
Shelley Canright, Ph.D.	Educational Technology Program Officer	
Donald James	ARC Education Director	
Mark Leon	LTP Manager	
Patrick Hogan	LTP Deputy Manager	
Alan Federman	LTP Staff	
Eileen Hutchison	LTP Staff	
Randy Kim	LTP Staff	
Tom Gaskins	LTP Staff	
<'03 LT Project Members>	LT Project Member (2003)	

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Table of Contents

Preface

This document describes the NASA Learning Technologies ExP initiative for science education software. It presents an overview of the initiative and defines ExP goals and requirements. Review and comment by all are welcome, and at any time. Please address comments or questions to phogan@mail.arc.nasa.gov.

1 ExP Overview

ExP is NASA's initiative to focus many of its educational software efforts towards long-lived, synergistic and on-line community based programs. This shift in focus is expected to increase the reach of NASA's science education efforts, and to better meet the modern needs of science educators and students. Rather than developing many small, independent education-technology programs, ExP forms several large programs that attract and support active communities of science and technology providers, curricula developers, teachers and students.

ExP uses its large audience to provide an important platform for educational technology and curriculum developers to target and to rally around. ExP gives these contributors greater visibility and reach of their investments. It makes their work less time-consuming and more likely to make a significant difference in a student's science education. It expands their impact.

ExP's foundation is a collection of software applications for learning science. These applications are supported with tailored lesson plans and timely science data, much of which is obtained live directly from NASA data feeds. Applications can be extended after installation with new data, additional capabilities and fresh lessons. ExP, itself, can be extended with new applications. On-line communities have formed around these applications and are expected to keep them active, timely and growing.

Educators and scientists are able to extend ExP lessons and data themselves; no programming is required. Science educators can focus on adding the science, not the software. This is a fundamental requirement of ExP.

ExP also gives software developers needed support for developing, packaging and releasing their applications and updates. It contains middleware for commonly needed features such as 3D rendering, data gathering, and collaboration. It provides tools and software to equip applications for accessibility by those with disabilities. It provides a framework to be part of and to develop for, and a large, existing audience to serve.

Lessons are as important as data in ExP. Guided inquiry introduces students to the curricula and applications. ExP offers many lesson examples as models for new lessons, and it provides guidelines for ensuring lessons meet standards for curricula, pedagogy, and applicability to organizational and government education goals.

All of ExP is available to the public. ExP is free to use, with the exception of a few outstanding but inexpensive commercial applications that can be licensed separately if desired. This commercial software is not required for use of the bulk of ExP.

A premise of ExP is that active, on-line communities are necessary to maintain, enhance and support useful software and thereby keep it valuable. The commercial and open-source software industries have taught us that software cost does not necessarily relate to software quality or value. Much of the best software today is open-source and free to use, and this trend is growing. The successful software efforts are those with active communities of developers, enhancers and users. By careful software selection and design – in many cases by selecting into ExP existing successful open-source efforts – Exp gathers the needed educational and development constituencies around NASA educational applications and supporting software.

ExP is meant to last and live indefinitely. It will continually evolve to meet new needs and to take advantage of newly accessible technology. The NASA Learning Technologies Office will manage ExP and move it forward through targeted investment in directly commissioned projects and competitively awarded grants.

1.1 What's In ExP

ExP provides three general sets of materials:

- Software applications that students use to follow lessons or explore independently.
- Lessons guiding students through the applications and directing their study.
- Software components and infrastructure to aid development of ExP applications.

1.2 ExP Applications

ExP software applications address the five NASA enterprises:

- Aerospace Technology
- Biological and Physical Research
- Earth Science
- Human Exploration and Development of Space
- Space Science

Each ExP application provides education in at least one of these areas, and frequently several. As ExP evolves it will seek to balance its coverage of these enterprises, but will remain opportunistic in incorporating compelling science education applications as they are newly conceived by the NASA community and the public domain.

Initial ExP applications – those incorporated in year 2003 – address all but the Human Exploration and Development of Space enterprise. The applications are:

- For Space Science, *Celestia*, a 3D application for exploring the Cosmos. Celestia enables students to move throughout the known Cosmos, from the local solar system to the remotest known galaxy. They can discover what is known about space objects, the relationship of those objects to near and far neighbors, and the science of an object's nature and existence. They learn the scale of the cosmos and discover the

immense distances, speeds and times required by space travel. A nearly infinite variety of lessons can be created for *Celestia*, and it can be augmented with additional space objects, their imagery, and their science information. *Celestia* is open-source, free to use, and supported by an active community of enthusiasts and educators. *Celestia* runs on mainstream, low cost PCs, under Microsoft, Linux and Apple operating systems.

- For Earth Science, NASA Goddard Space Flight Center is developing a 3D Earth viewer able to take students from a near-Earth space view to one-meter surface resolution. Students can quickly and interactively navigate to any Earth location and vantage point. They can view space- or time-based data in the context of the Earth and its true and current imagery. By selecting auxiliary data sets, students can view physical phenomena such as bathymetry and thermal characteristics, both static and dynamic. A virtually unlimited collection of Earth Science information can be made available simply by forming new data sets appropriately or by linking to public NASA data sites and feeds. Lessons can be written for the out-of-the-box viewer data or for new data. *Digital Earth Viewer* runs on mainstream, low cost PCs, initially under Linux, but eventually under Microsoft, and Apple operating systems.

- Physical Research is supported in ExP initially through *NASA Virtual Lab*, an application under development at Kennedy Space Center. Targeted towards advanced high school students, college undergraduates, and technology school students, *Virtual Lab* provides interactive education on sophisticated instruments such as scanning electron microscopes and mass spectrometers. Lessons focus on the art and technique of operating the instrument, or on the exploration and study of specimens. The instruments and the specimens are virtual. New specimens can be created without modifying the *Virtual Lab* application. New instruments can be programmed and incorporated into the Lab. Lessons can involve one or many instruments and one or many specimens. A community of scientists, engineers and educators creates the specimens, programs new instruments, and develops the lessons. As required by ExP, *Virtual Lab* runs on all common computer operating systems and requires only mainstream personal computers and input devices. It is free to use and to extend.

ExP applications are required to be visually rich and engaging. They are ideally as appealing as a good video game, complete with 3D graphics and interaction, inviting backgrounds and environments, and interesting and compelling goals. Where appropriate they use sound, force feedback and visual immersion. As computer devices evolve and become inexpensive, ExP applications will incorporate haptic gloves, wands, and multi-screen displays. New technologies that come available will be usefully applied.

ExP applications run at interactive rates on the low-cost computers typically found in classrooms. The applications are in most cases free, and in many cases open-source. Expense is not a barrier to obtaining and using any ExP application, either at school or at home.

While many ExP applications interact with the world-wide-web, they are mostly local applications, choosing to avoid the limitations of web pages. They can take advantage of running locally to create an immersive experience and to achieve best performance and flexibility. They use the web and the internet appropriately for data gathering and interactive collaboration. They are downloaded and updated through the web.

NASA science, data and expertise is the source for ExP applications. Whether the applications are created within NASA or outside NASA, their content and lessons reflect science that NASA is truly engaged in. Their data is almost always drawn from NASA sources. NASA scientists and educators are intimately involved in all ExP projects.

To be part of ExP, an application must be general enough to support many lessons. Educators must be able to create lessons for an application independently of the application developers, and without writing software.

This independence includes the ability to add new data. An ExP application for learning about the Solar System, for example, has the ability to receive new or updated imagery, geology information or planetary object data, obtained and incorporated by the educators developing the related curriculum. Tools to do this and perhaps some data formatting may be required, but software changes to the application are not.

Similarly, applications should be open and flexible enough to allow feature extension by the addition of independently developed software modules.

1.3 ExP Lessons

ExP lessons guide students towards learning specific concepts or details. They vary considerably in their content, level of detail and degree of direction. Some educators will give only general guidance in the lessons they create; others will provide step-by-step instructions. The content of lessons is the decision of the educators creating them.

Each ExP application has many lessons associated with it. Lessons are a requirement for application inclusion in ExP. The application authors or their education partners create the initial lessons. The community around the application creates new lessons and keeps the application's entire lesson set up-to-date. Lesson creation can go on indefinitely, as it will in a vibrant application community.

Lessons are in many ways the primary deliverable of ExP. Applications are merely in service of them. It's the lessons that guide student inquiry. It's the lessons that capture the pedagogical intent of the educator.

ExP Lessons are free to use by anyone, including classroom teachers, museum docents and independent-study students.

Lessons are in the form of electronic documents, instructions on web-pages, or perhaps programmed into an application itself, if the application has that ability. Their form is left to the discretion and resources of the educator.

Lesson content, however, should follow ExP lesson guidelines. These guidelines recommend that lessons identify the educational standards they cover or adhere to, and that they be inquiry based. They should lead students through an exploration rather than simply presenting facts or marching the student from one screen to the next. Ideally, lessons help students learn more about the application so they can explore on their own, beyond the lesson material

Lessons should contain instructions to educators and students indicating their target audience, e.g., K-12, their level of difficulty, and references that help a teacher or student assess whether the lesson is appropriate for their needs.

ExP provides example lessons that lesson creators can emulate or draw ideas from. It also provides expert pedagogical advice for teaching through software applications like those in ExP. This advice is from distinguished educators commissioned specifically to develop ExP lesson guidance. ExP's example lessons have been reviewed – and in many cases, created – by expert educators who evaluated them for lesson pedagogy, appropriateness to the target audience, and quality. They are excellent material to base new lessons on.

1.4 ExP Software Components and Infrastructure

The applications in ExP are significant engineering achievements. Like any engineering endeavor, they benefit from using standardized technology and common components for popular features. Image processing, 3D graphics, and internet data access are just a few of the features used widely in engaging, modern applications. Many of these capabilities have existing, essentially off-the-shelf software solutions that can save application developers the time and expense of creating the capabilities themselves. ExP identifies these solutions and makes them easily available to ExP application developers.

Initial (year 2003) ExP software components serve the following needs:

- Internet data access mechanisms to NASA Earth, planetary and space data
- Image processing
- 3D graphics and visualization
- Display and device management, and application control

Software solutions for all these needs exist now. Some of them – especially data access mechanisms – are available within NASA and have their own software initiatives in progress. ExP will utilize these existing solutions.

Likewise, packaging, delivering and updating software are significant efforts. ExP and the Learning Technologies Office simplify these tasks by providing state-of-the-art tools for packaging and delivering ExP applications and updating them on the user's computer after installation. Additionally, ExP provides guidelines for delivering software and data in the form of a familiar ExP component.

ExP maintains a public web site for application description and download. Current versions of ExP applications are always available there for anonymous download. The site is the also repository for post-installation application updates.

The goal of the software component and infrastructure portion of ExP is to make ExP application development simpler, and to make it more timely with respect to both time-to-delivery and state-of-the-art features and device support.

Besides being selected for their functionality, ExP software components are selected for their ability to enable high-technology features on mainstream computers. The target platforms for all ExP applications are those that run in public classrooms of K-12 schools. Because the ExP staff and community continually research, evaluate and recommend software that brings out the best in these computers, ExP applications that use this software automatically run optimally on these devices.

NASA also uses ExP as a platform to expose timely new software capabilities with potential for widespread use in science education. An example under development is sonification of time-series data, primarily to aid interaction with data by blind persons, but potentially advantageous to all. By developing this NASA technology as componentry, the capability is easily adopted by many applications.

ExP components are also judged on their openness. Open-source software is preferred because it allows application developers to enhance or repair the software to meet their specific needs. Actively maintained open-source software has the advantage of fast repair and enhancement turn-around, as well as a responsive community of experts to offer help and advice.

As with ExP applications and lessons, ExP componentry and infrastructure evolve and grow with need and opportunity. Initial components and services are those identified by the first ExP community. Additions, updates and replacements occur as needs are identified by the growing community and technology becomes available. New technology will be commissioned or adopted when requirements and opportunities arise.

2 ExP Requirement Details

Details of the ExP requirements are listed in this section. These details echo the descriptive presentation above, but in some cases provide additional specifics. As mentioned in the Preface, ExP is constantly evolving, therefore the set of requirements listed here will change and grow.

2.1 Application Requirements

1. Applications must have an educational, inquiry-based focus.

2. ExP applications must be sensorily rich and engaging. They are ideally as appealing as a good video game, complete with 3D graphics and interaction, inviting backgrounds and environments, and interesting and compelling goals. Where

appropriate they use sound, sensory feedback, and visual immersion (multiple display surfaces).

3. Applications must reflect science or missions that NASA is truly engaged in. While applications need not confine themselves to topics of the five NASA enterprises, they must address at least one of those enterprises or the skills that support them (e.g., Mathematics, Physiology, Astronomy).

4. The potential to build a community of users, educators and developers around the application must exist, or such a community must already exist.

5. Applications must run at interactive rates on low-cost computers typically used by students in classrooms. They must operate on computer hardware and operating systems available in classrooms, including, at a minimum, personal computers running Microsoft, Linux and Apple operating systems.

6. Applications must be free to use, or require at most a single, low-cost license for unlimited site or home usage per organization – school, school district, museum, family, etc. Expense must not be a barrier to obtaining and using any ExP application, either at school or at home.

7. Applications must be sufficiently general to support many lessons. They must have at least ten lessons available upon initial release into ExP.

8. Educators must be able to create lessons for an application independently of the application developers, and without writing software.

9. It must be possible to add enriching or updated source or display data to the application without reprogramming or otherwise modifying the application's source code, and without having to create software extensions to the application.

10. Applications should be sufficiently open and flexible to allow feature extension by the addition of independently developed software modules or extensions. Their source code and supporting material should be freely available.

2.2 Lesson Requirements

1. Lessons should be inquiry-based, leading the student through exploration. They must allow the students to control their progression through the lesson.

2. Lessons must be freely accessible and free to use. They must exist in a format readily accessible by students in public school classrooms.

3. Lessons must be professional quality and comprehensive relative to their goals.

4. Lessons should identify the relevant government standards they support, and the pedagogical methods or theories they use.

5. Lessons should contain a means to evaluate or indicate student learning of the lesson material. E.g., worksheets, quizzes, pre- and post-lesson evaluations.

6. Lessons must be based on one or more ExP applications.

2.3 Software Component and Infrastructure Requirements

1. ExP software components must support the needs of ExP software applications or the process of building lessons for those applications.

2. The potential to build a community of users, educators and developers around the components must exist, or such a community must already exist.

3. Components must be consistent with or in support of application requirements to run at interactive rates on low-cost computers typically used by students in classrooms. Components must operate on computer hardware and operating systems available in classrooms, including, at a minimum, personal computers running Microsoft, Linux or Apple operating systems.

4. Components must be free to use, or require at most a single, low-cost license for unlimited site or home usage per organization – school, school district, museum, family, etc. Expense must not be a barrier to obtaining and using any ExP application, either at school or at home.

5. Components should be sufficiently open and flexible to allow extension by independent software developers. Their source code and supporting material should be freely available.

6. Components must be well documented for their target audience. For software components, the target audience is typically software developers. Educators are typically the target audience for lesson-building tools.

7. The LT Office provides component consulting and guidance to developers and lesson builders. Application authors or sponsors, and lesson builders must supply any necessary guidance and consulting to application and lesson users.

8. The LT Office provides guidance and direct support for packaging, releasing and updating ExP applications and components. The LT Office manages and maintains the ExP distribution site and materials.

9. The LT Office, in conjunction with others in the NASA community, continually evaluates candidate entrants to ExP, and selects the entrants.

10. The LT Office manages and maintains any software that is not part of a separate on-line community.

11. The LT Office purchases any necessary licenses for software infrastructure applications or support, e.g. commercial packaging and distribution utilities.

3 Definitions, Acronyms, Abbreviations

ExP	NASA Learning Technologies **Ex**periential **P**latform
Cross-platform	Operates equivalently on personal computers running Microsoft, Linux and Apple operating systems.
LT Office	NASA Ames Learning Technology Office
may	Indicates a requirement that is desirable to achieve, but not necessary.
must	Indicates a "hard" requirement that is necessary to meet completely.
Open-source	Software whose source code and development materials are public, visible and accessible. The software is free to use and extend. It typically has an open, on-line community supporting it. Several licensing schemes are used, but the open-source intent is to make software available and unencumbered for non-commercial use.
should	Indicates a requirement that is strongly encouraged, and relaxed only with special consideration.