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KSC Education Technology Research and Development Plan

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ABSTRACT

Educational technology is facilitating new approaches to teaching and learning science, technology, engineering, and mathematics (STEM) education. Cognitive research is beginning to inform educators about how students learn providing a basis for design of more effective learning environments incorporating technology. At the same time, access to computers, the Internet and other technology tools are becoming common features in K-20 classrooms. Encouraged by these developments, STEM educators are transforming traditional STEM education into active learning environments that hold the promise of enhancing learning. This document illustrates the use of technology in STEM education today, identifies possible areas of development, links this development to the NASA Strategic Plan, and makes recommendations for the Kennedy Space Center (KSC) Education Office for consideration in the research, development, and design of new educational technologies and applications.

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1. INTRODUCTION

Educational technology is facilitating new approaches to teaching and learning science, technology, engineering, and mathematics (STEM) education. Cognitive research is beginning to inform educators about how students learn [1] providing a basis for design of more effective learning environments incorporating technology. At the same time, access to computers, the Internet and other technology tools are becoming common features in K-20 classrooms. Encouraged by these developments, STEM educators are transforming traditional STEM education into active learning environments that hold the promise of enhancing learning.

Educational technology can facilitate meeting the education goals of the NASA Strategic Plan [2] and the draft NASA Education Enterprise Strategy [3]. To achieve the education goals outlined in the strategic plan, Kennedy Space Center (KSC) should utilize existing and develop new educational technologies to improve STEM education and enhance public awareness. The availability of the Internet in schools and homes provides a unique opportunity to reach more customers than ever before.

The Internet provides an access point for educators and the general public to access programs and products developed at KSC. The NASA Education Enterprise has set a number of metrics for increasing participation of students, educators and the general public by 20% by the year 2008. Educational technologies and the Internet can facilitate this target growth. Utilizing the Internet, KSC can provide programs, access to resources and products (downloads), and e-learning opportunities at all levels.

2. CURRENT EDUCATIONAL TECHNOLOGY PRACTICES

Many states have adopted or integrated the National Educational Technology Standards [4] (NETS) developed by the International Society for Technology in Education (ISTE) into state and local standards. By examining the NETS, stem educators and designers can gain an insight into how technology is being utilized in the K-12 and teacher preparation arenas. A second organization, the International Technology Education Association (ITEA) has also developed technology standards focusing on developing a technology literate populace [5]. ITEA is focusing on the ability to use, manage, and understand technology.

The National Science Teachers Association (NSTA) has addressed the role of computers and developed a set of guidelines for use in science education. The National Science Education Standards (NSES) [6] and American Association for the Advancement of Science (AAAS) Benchmarks [7] also address technology as it relates to science. The National Council of Teachers of Mathematics also addresses the teaching of mathematics utilizing technologies such as calculators and mathematical software. NCTM [8,9] recognizes that technology is an essential component of the future mathematics-learning environment. In contrast to the NETS standards, the STEM standards provide a focus for future development of tools and applications that may enhance STEM learning.

In addition to the standards and reform documents, cognitive science is providing insights into how people learn. These insights should be taken into consideration as KSC develops new educational technologies and applications to enhance STEM learning. In the book, "How People Learn" [1], evidence is presented to demonstrate that technology can play an effective role in supporting six practices that can improve STEM learning. These six practices are: 1) visualization, 2) simulation, 3) problem solving, 4) collaboration, 5) inquiry and 6) design. The following sections will describe specific uses of educational technology and the Internet.

3. COMMON USES OF EDUCATIONAL TECHNOLOGIES

As part of this project a survey was prepared in July to poll teachers about their current use of educational technology and the Internet. The participants were attending an educational technology conference in Washington, D.C. Twenty-six teachers participated in the survey. The teachers were from 7 states and the average experience of the teachers was 17 years in the classroom. All of the teachers who participated in the survey and follow-up focus group discussions were actively involved in a US Department of Education (US Ed) Technology Challenge Grant.

Teachers reported that they primarily utilize productivity (word-processing) and presentation (PowerPoint) software to support instruction in their classes. During follow-up focus groups, teachers reported that these tools came with the computers and their students were more likely to have access to these at home. Multimedia was primarily used to support teacher presentations and student research projects. Over 35% of the teachers utilized GIS and GPS in their classrooms. At first this may seem to be a significant number, however all of the teachers were trained in the use of GIS and GPS technologies and were required to use it as part of the TICG grant. 40% of the teachers utilized cognitive programs in their classroom. These programs allow students to illustrate their thinking by creating cognitive maps or concept webs. These programs were demonstrated in year one of the grant and a significant number of teachers were using them four years later. Teachers informed the researcher that they found these programs easy to use and beneficial to students.

Surveyed teachers use of the Internet supports conclusions in the research literature. In spite of their involvement in an educational technology project, teachers primarily utilized the Internet as a resource to support student research projects. Its other major use was for communication, primarily email. All of the teachers had been required to participate in online courses (e-learning) for professional development. 100% of the teachers found e-learning to be beneficial due to its flexibility and availability. Discussion during the focus group supports the development of online strategies to train and provide professional development to teachers. As a result of participation in project related online classes, over 50% of the teachers involved in this survey, enrolled in and are completing a Master of Education degree online. The pursuit of the degree is not funded by the grant.

Teachers were also surveyed regarding barriers to using technology in the classroom. Barriers primarily included cost of equipment and software, lack of high speed Internet access, lack of training, and lack of time. Teachers were very interested in educational technology that would allow them to teach concepts in a time effective manner. Teachers were particularly interested in having experts; such as NASA scientists connect with their classroom via email, chat or video conferencing. Teachers were also very interested (70%) in participating in online virtual tours and professional development programs available through NASA.

Based on the literature and supported by the study above, it appears the most common use of computer technology and the Internet is accessing educational resources. These resources can be online or on CD-ROM/DVD. The Internet has made available a broad range of information resources and these resources are helping equalize access to quality materials.

The e-learning medium is one of the fastest growing arenas in education. Universities and K-12 systems are using e-learning to deliver courses and programs, provide information to stakeholders, and create opportunities for greater collaboration. Many e-learning strategies focus on more administrative functions, access to course materials, and online discussions. E-learning technology can allow teaching and learning to be transformed in new ways. Many instructors choose to use e-learning tools to post lectures, homework, and quizzes. E-learning can be enhanced to expand the boundaries of the classroom. Strategies such as web-casting, e-mentoring and tutoring, and virtual field trips can allow students to communicate with experts and go into the field. E-learning products can also be enhanced with visualization and simulation tools. NASA, in its Strategic Plan, recognizes the potential of e-learning and has defined objectives that will lead to the creation of a NASA E Learning Infrastructure. This type of learning is already being implemented in the NASA Explorer Schools, NOVA and by NASA's Classroom of the Future.

4. EMERGING USES OF EDUCATIONAL TECHNOLOGIES

Visualizations

The ability to visualize has been linked to increased student achievement in mathematics and science [10]. Visualization tools are vehicles for helping students understand difficult abstract concepts. For example, students who have difficulty in visualization of science concepts often have difficulty in learning the content. Educational technology can provide three-dimensional visualizations to overcome these problems. Computers provide a way to move beyond static two-dimensional representations of three-dimensional phenomena and provide platforms that simulate reality. Current molecular modeling software can alternate images of a given object at rates approaching thousands of times per second, creating a realistic three-dimensional effect [11, 12].

As computers get faster, software developers can now produce pedagogical software that was not possible 5 years ago. This is an opportunity for NASA to sponsor and create new STEM visualization tools. NASA's Learning Technology Program (LTP) has developed a number of visualization tools for STEM education. Many other visualization tools are finding a place in the curriculum. Spreadsheets and graphing calculators are now widely used for mathematical modeling. NASA makes available large databases of all types to educators. These include image databases, media databases, and raw data archives from NASA missions.

Other visualization techniques include video-based laboratories. Video-based labs can help students understand concepts in physics. KSC public affairs has an archive of video that could be utilized. For example students can use the pause and frame-by-frame features on a CD or DVD to examine motion involved in transportation (a space shuttle take-off or landing) [13].

Simulations

Simulations allow students to examine complex systems by looking at the parts simultaneously or sequentially. In the case of Earth systems, output data can be displayed graphically and on maps at the same time. The map and the graph can be linked so that as the user manipulates variables, changes on the graph and map occur simultaneously. NASA has funded STEM education simulations. One of the most recognized is the BioBLAST CD created by NASA's Classroom of the Future. BioBLAST is a multimedia supplemental curriculum for high school biology classes. Students conduct scientific research, based on actual research now being conducted by NASA's Advanced Life Support Research program. Simulations can also replace experiments that may be too costly or risky to perform. Simulations can also save time over live experiments that require more time than is available in a class period. Simulations are a reasonable alternative.

Problem Solving

NASA is currently exploring many questions that will only be answered over long periods of time. Is our planet experiencing global warming? The answer to this and other problems are complex. Providing opportunities for students to develop their problem-solving skills is becoming a high priority for STEM educators. Many new curricula are being created around real-world problems. For example, NASA's classroom of the future has created an interdisciplinary program, *Exploring the Environment,* to provide educators with real-world problems for students to study. The curriculum uses a problem-based learning (PBL) approach. Students explore real-world problems and utilize NASA data to look for patterns and pose solutions. As students explore real-world problems, they can communicate with one another, with their instructors, and with professionals (i.e. NASA Scientists and Engineers).

Collaboration

Today STEM research usually involves collaboration among colleagues. Educators need to provide students the opportunity to participate in collaborative projects. Students can develop teamwork skills using modern information technology as a tool. Projects can be done via the web with participants from all over the world. An example of this is the NASA funded GLOBE program. GLOBE is an Internet-based program that promotes collaboration between schools and scientists researching the environment. Through a web interface, GLOBE provides communication and research tools online for students and faculty. Other forms of collaboration include interactive web-casts, online mentoring and tutoring.

Inquiry

The *National Science Education Standards* emphasize inquiry as a means of learning fundamental scientific concepts. Technology can provide opportunities for learners to conduct their own investigations of real problems. In addition to working with data generated or collected by others, technology enables students to collect and analyze their own scientific data. Many science programs use computer-interfaced sensors to measure different phenomenon. Many of these can be used with handheld calculators, battery-operated computer-based laboratory interfaces, and personal data assistants, making them opportune for fieldwork. The NASA Explorer Schools Program is utilizing PDA's to collect data in middle school science classrooms. Students can also use calculators and software to manipulate and analyze large data sets with statistical tests, simulate models, and draw conclusions based on the outcomes of these actions.

Design

Computer-aided design (CAD) allows students to design objects for the real world. CAD instruction provides important workplace skills. As distance education and collaboration between individuals at different sites become more common, the use of design tools that can be transmitted over the Internet will likely increase [11]. Designers can build a sequence of visual images into web settings, while users can view, move and rotate those images. The work at KSC involves many engineering design activities.

5. THE FUTURE ROLE OF TECHNOLOGY IN EDUCATION

It is important to take into account the current educational environment before proposing the development of any new technologies or applications. Educators are under increasing scrutiny and pressure to produce positive results. The U.S. government is now interested in the research base for programs, strategies and products that schools adopt. The emphasis is on evaluations that use experimental or quasi-experimental designs, preferably with random assignment. Schools, districts, and states must justify the programs that they expect to implement under federal funding. KSC needs to consider the accountability issue when developing products and programs.

Unfortunately, there is currently a lack of valid and reliable instruments for measuring the effectiveness of new teaching and learning approaches that incorporate technology. This poses a barrier to the diffusion of these new approaches and products. New product development will require developers to assess learning by students utilizing new products. Data should be used for formative purposes as well as summative. Development of new educational technologies and programs need to consider how to improve alignment between instructional goals and assessment. Assessment mechanisms should be built in wherever possible to provide feedback to teachers and students.

Future educational technology development should also focus on the learner and be based on current cognitive research. Increased research and development are required to develop the potential of educational technologies to improve pedagogy and enhance STEM learning.

The report, Visions 2020 [14], provides a vision of e-learning in the year 2020 illustrating education technologies such as ubiquitous computing, global access, rich communication (visual), and highly interactive 3-D environments. This proposed future aligns well with NASA's objectives for e-learning. The biggest future leap appears to be the emergence of immersive 3-dimensional environments, where students will be able to explore any place or object. Students will be able to walk through and rearrange atomic structures, travel to far away places, or explore virtual worlds.

What should be developed?

Technology and reform initiatives are rapidly changing education. It is not possible to accurately predict the future impact technology will have on STEM education. Future development cannot solely be based on current trends. KSC will need to identify factors influencing development of technologies that: (1) might be useful in STEM education, and (2) might influence implementation of those technologies over the next 5 years. The previous sections of this document outline the 6 areas that KSC should consider developing.

6. RECOMMENDATIONS FOR RESEARCH AND DEVELOPMENT

KSC should adopt a scientific approach to developing educational technology tools and resources. Developers and researchers should formulate a hypothesis about what technologies are most likely to achieve the educational goal, and develop a protocol for evaluating progress toward the goal.

Research and development funding from NASA has been critical in developing the innovative e-learning courses through COTF, ESE, NOVA and e-learning tools through LTP. NASA should build upon the successes of these programs. KSC should consider partnering with private companies, professional organizations and public/private education institutions to forward its efforts in educational technology. Through partnerships, NASA could support individual faculty and education institutions as they take a scientific approach to deploying technology in STEM education. The focus of research, development, and demonstration should be on student learning and quality of instruction rather than on any particular technological tools. There is a need for further research that would examine how best to use this technology for STEM educational purposes. Three general recommendations for KSC are:

- Virtual Classrooms, Virtual and Remote Laboratories, and Distance Education. This area encompasses long-distance collaboration among students, teachers, mentors, and experts; access to classrooms remote from the student; as well as educational resources not locally available. KSC should try to take a lead role in the development of one of the four e-learning technologies described in the strategic plan.

- Innovation in Curriculum Content. This area encompasses scientific and mathematical modeling, support for collaborative projects, access to and use of data sources, and support for modeling large data sets or complex processes, all of which enable learning through real-world experimentation. Where appropriate, measurement tools should be embedded in learning activities; tools for identifying specific content and methodological strengths and weaknesses of the learner; teacher-oriented measurement; and organization tools should be incorporated.

- Create a research group to develop a scientific approach to the development of educational technology products to support STEM education and their implementation and dissemination. This could include the standardization of learning objects and content so that the greatest number of users can take advantage of KSC developed or sponsored educational technologies.

Before development of any new educational technology products begins, KSC should determine its target grade levels for product/program development based on need. It is recommended that KSC sponsor a symposium of educators (potential users) and developers to discuss classroom needs for teaching STEM disciplines. Too often developers receive their grant funds and the education input comes after the development as part of testing the new product. The end-users need to be included in the planning.

All K-12 products should conform to the standards and a priority should be given to products/programs that can demonstrate a direct connection to the standards and show promise for increasing STEM student achievement if it is to be used in the formal classroom environment. The Third International Mathematics and Science Study (TIMSS) can provide a roadmap for what discipline and content development is needed.

For guidance in content development, AAAS and the National Science Teachers Association have co-published the "Atlas of Science Literacy" [16], a collection of 49 conceptual strand maps that show how students' understanding of the ideas and skills that lead to literacy in science, mathematics, and technology might grow over time. Each map depicts how K–12 learning goals for a particular topic relate to each other and progress from one grade level to the next. These maps can facilitate more meaningful content development connected to the standards.

Development in higher education should revolve around teacher preparation given the interest in improving teacher quality by the current administration. TIMSS [16] data reflect that US students' scores tend to drop following 4^{th} grade as compared to their international counterparts. This trend would support that products focusing on better teacher preparation of grades 5-12 students might produce the greatest return on investment. As students enter these grades, science topics become more abstract and quantitative. Many teachers teaching science at the middle level may have a generalist certification. High school teachers, especially in chemistry and physics may be teaching out of field. Programs and tools that focus on just in time learning and tools to help students visualize concepts would be one area to focus. For example, KSC could partner with NSTA as it builds Science Learning Objects. A learning object as defined by NSTA is one content strand from the Atlas delivered via the Internet. KSC could create the objects related to its mission.

Professional and academic engineers, scientists, mathematicians and STEM educators should convene to discuss development for higher education and preservice. Informal educators should be convened to discuss development for informal education.

7. CONCLUSIONS

Future funding is always a variable in carrying out a production plan. KSC will need to secure funding sources from within NASA and externally by partnering with other agencies, industry, professional organizations, informal education and higher education. The following recommendations are provided.

- KSC and its potential partners need to be aware of the educational environment and policies that could affect the successful implementation of any technologies for a given audience. KSC could sponsor a symposium (live or online) or attend programs sponsored by US Ed and NSF to stay abreast of the changing education environment. There are also several educational technology conferences that could benefit from KSC participation.

- KSC needs to create and maintain a database/inventory of potential learning objects that have already been created. For example, the KSC Public Affairs website has links to a number of ISS videos that could be incorporated into physical science learning applications. KSC should also reexamine its website and consider a redesign to create an educator friendly site. KSC also needs to examine archived sites to determine which sites should be retained or eliminated.

- KSC should conduct a needs assessment in its service area to better facilitate planning. Results should be stored in a database for future reference. In many cases, surveyed educators may be unaware how technologies can assist STEM instruction. If the survey is properly constructed, this information could become apparent. After needs assessments are completed, KSC should base development on scientifically sound research and should plan to embed assessments within proposed products and programs.

- The Education Office at KSC should conduct an assessment of the different KSC research programs to identify potential products or modification of existing ones. Some NASA research programs require a percentage of funds to be spent on education and outreach. KSC Education staff should offer their expertise to assist these researchers in preparing the education and outreach sections of proposals.

- KSC should focus on products that can be delivered or downloaded over the Internet. The Internet offers a cost-effective means to delivering programs and providing products. Many of the elements of these products already exist at KSC. KSC should develop advanced visualizations and simulations based upon the standards and the AAAS "Atlas". These applications could be similar to the Virtual Lab KSC is now developing through NASA LTP.

As KSC builds its research capacity, the education office may want to develop expertise in the area of educational technology research and assessment. Once a product has been developed and tested, KSC should publish the results of the field test and report the effectiveness of the product/program. Effective products should be disseminated via the Internet, NASA Educators Resource Center Network, Space Grant and CORE. Opportunities for training end-users should be available to inservice and preservice teachers live and/or online.

8. REFERENCES

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