SPACE
one giant leap for education
The Space Studies Program (SSP) 2012 Program of the International Space University (ISU) was held at Florida Institute of Technology in partnership with NASA Kennedy Space Center in Melbourne, Florida, USA.

The cover of this report shows two stylized children dressed as astronauts and a spaceship styled after an artist’s brush floating in space over the Earth. The background for the cover is a star-scape image taken by the Hubble Space Telescope and is used courtesy of NASA.

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Abstract

Science, technology, engineering, and mathematics (STEM) are fundamental fields to modern society. Unfortunately, many countries are experiencing a decreasing student interest in STEM disciplines that threatens their long-term productivity and international success. This report answers the question, “What can space contribute to global STEM education?” Space has a wide appeal, the power to inspire, and collaborative international background that can encourage students to engage with their studies and pursue higher education in STEM fields. Every country needs a strong STEM workforce tailored to its specific economic, social, and cultural situation.

This report shows that the state of STEM education in different countries is dependent on economic situation, political motivations, gender, culture, and social class. Educational materials have evolved significantly over time; however, the way they are taught has remained constant. The use of art within STEM education was reviewed and found to be an effective tool to introduce STEM students to a different manner of thinking and to foster creative thought.

This report describes ways to use space to improve STEM education and reach a broader audience. Space-related content can be integrated into existing academic curriculum delivered by STEM teachers and into non-school materials accessed directly by students and their families. The suggested programs and interventions are: space workshops; a space debris game; integration with the World Space Week; on-orbit student competitions; adding space-related examples to textbooks; adding a space section within the Khan Academy online learning resources; and a video outreach program.

Space can improve STEM education by attracting and motivating students. Space-related content can help students understand the relevance of STEM in their lives and studies. Space activities provide a shared experience for people of different countries and can promote cultural acceptance, expand international cooperation, and reduce social gaps. Space-related content can provide a Giant Leap for Education!
FACULTY PREFACE

The current evolution of technology, organizations, and people on planet Earth fosters new endeavors in STEM education. In some developed countries young people are less interested in STEM education, and we need to find out what kinds of education the new generation of designers, builders, and creators will need to develop life-critical systems such as clear water supply, safe and reliable transportation systems, good and affordable medical assistance, as well as energy control and management.

The Cold War energized the space race, and space contributed to STEM education by providing incentives and motivation in research, development, and manufacturing. Tremendous progress in technology has been made between the Second World War and the end of the Twentieth Century. Today’s framework is heavily dependent on international cooperation in space business, industry, and research. It is time to think about what we will need in the near future to build new spacecraft, organize new missions, and train people in new fields to explore our universe. Our information society is intimately interconnected; information and knowledge are now accessible anytime and anywhere. How will the new generation be educated to handle the new challenges to their perception, comprehension, and projection?

Participants to the International Space University – Space Studies Program 2012 Team Project, consisting of graduate students and space professionals from seventeen countries, carried out an important research effort to better understand what space can bring to global STEM education. This effort was carried out at the Florida Institute of Technology, Melbourne, Florida, USA, from 4 June to 3 August 2012. The team was supported by a series of site visits, workshops, and lectures given by international speakers, such as three former astronauts, Leland Melvin [National Aeronautics and Space Administration (NASA)], Jean-Jacques Favier [Centre National d’Etudes Spatiales (CNES)] and Chiaki Mukai [Japan Aerospace Exploration Agency (JAXA)], involved in various kinds of STEM activities. The team was supported by Caroline Hardman (National Network of Digital Schools), Jacques Arnould (CNES), Carlos Niederstrasser (Orbital Science Corporation), Bill Nye (Planetary Society), Remy Bourganel (École nationale supérieure des Arts Décoratifs), Cristina Olivotto (Sterrenlab), and the Kennedy Space Center (KSC) education team. These contributions are an important interdisciplinary and intercultural input to the team’s work. The team accomplished a remarkable amount of work in literature research, content analysis, discussions, and projection into possible futures.

The team investigated whether STEM should be integrated with art. Designing new space architectures requires creativity and rigorous methods. Human-centered design is a great direction for future education where complexity should be analyzed and not avoided. Technology cannot be developed without accounting for organizational issues and co-developments. Advanced interaction media systems, modeling, and simulation are at the center of new technological developments. All this requires passion and commitment. It requires a goal-driven approach to technology, organizations, and people (Boy, 2012).

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This report represents nine weeks of applied studies, animated discussion, creative experimentation, and intensive research by an international, intercultural, and interdisciplinary group of 34 SSP12 participants from 17 countries. The team was united by a common love of space, and the common goals to review the global state of STEM education and brighten humanity’s future by answering the question “What can space contribute to global STEM education?”

The drivers behind the project were as varied as the participants. Some team members had discouraging educational backgrounds in STEM studies, and wanted to ensure all students today have equal and beneficial education. Others had positive school experiences and wanted to provide the same for future students. Many participants wanted to do their part to benefit their country by learning from the systems of other countries. All team members wanted to make an active, critical, and personal contribution to improve the world.

Over the course of the team’s work, it became clear that there is an urgent need to combat the declining interest in STEM subjects and improve the quality of STEM education. While particular issues vary depending on social, cultural, economic, and geographical factors, space provides solutions that rise above these differences. Space is an inspirational, unifying, and outstanding vehicle for STEM learning. When applied with purposeful creativity, space breathes new life into STEM education and revives it for new generations of children.

Working collaboratively presented many challenges. The team was fully aware that this report stands as a test of global cooperation, creativity, and tenacity. Small details required many hours of group discussion. An all-voices-heard approach was followed. Out of this hard effort, an understanding emerged: positive global change requires a fine balancing act of patience, action, and good humour.

Team Project STEM – “Space: One Giant Leap for Education”

ISU SSP12
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<tr>
<th>Acronym</th>
<th>Full Form</th>
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<tr>
<td>CASIS</td>
<td>Center for the Advancement of Science in Space</td>
</tr>
<tr>
<td>CNES</td>
<td>Centre National d’Études Spatiales</td>
</tr>
<tr>
<td>CNSA</td>
<td>Chinese National Space Administration</td>
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<td>CREDO</td>
<td>Stanford Center for Research on Education Outcomes</td>
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<td>CSA</td>
<td>Canadian Space Agency</td>
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<td>DNA</td>
<td>Deoxyribonucleic Acid</td>
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<td>ESA</td>
<td>European Space Agency</td>
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<td>ESERO</td>
<td>European Space Education Resource Office</td>
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<td>IMAX</td>
<td>Image Maximum</td>
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<td>IMO</td>
<td>International Mathematics Olympiad</td>
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<td>ISAC</td>
<td>International Space Apps Challenge</td>
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<td>ISEB</td>
<td>International Space Education Board</td>
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<td>ISRO</td>
<td>Indian Space Research Organization</td>
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<td>ISS</td>
<td>International Space Station</td>
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<td>ISU</td>
<td>International Space University</td>
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<td>JAXA</td>
<td>Japan Aerospace Exploration Agency</td>
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<td>JST</td>
<td>Japan Science and Technology Agency</td>
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<td>JPL</td>
<td>Jet Propulsion Laboratory</td>
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<td>KSC</td>
<td>Kennedy Space Center</td>
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<td>MEXT</td>
<td>Ministry of Education, Culture, Sports, Science and Technology</td>
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<td>NASA</td>
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<td>OECD</td>
<td>Organization for Economic Co-operation and Development</td>
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<td>Programme for International Student Assessment</td>
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<td>Science, Technology, Engineering, Art, and Mathematics</td>
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<td>STEM</td>
<td>Science, Technology, Engineering, and Mathematics</td>
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<td>TIMSS</td>
<td>Trends International Mathematics and Science Study</td>
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<td>UNOOSA</td>
<td>United Nations Office for Outer Space Affairs</td>
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<td>US(A)</td>
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1 INTRODUCTION

What can space contribute to global STEM education? This is the question to be addressed by this report. As stated in the ISU SSP Handbook (2012), “Space still captures the imagination of many young people around the world and has the potential to open the frontiers of Science, Technology, Engineering, and Mathematics (STEM) to many participants.”

The STEM fields are fundamental to modern society; however, it has recently been noted that there is a perceived lack of interest and fear of these subjects among students (Lenovo, 2011). The rationales behind these misgivings are varied, both in culture and geographic region. The goal of this report is to show that using space as a source of inspiration can improve the quality and accessibility of STEM fields. It is essential that young people are given the chance to develop and sustain an interest in STEM fields, as these fields are essential to societal progress. Through its wide appeal, power to inspire, and collaborative international traits, space can be a powerful tool to encourage students in their studies.

1.1 What is the STEM Problem?

Students versed in the STEM fields will become the innovators of tomorrow. STEM education produces the critical thinkers needed to generate the products and processes that will sustain the world economy and human well-being. Of the 20 fastest growing careers in the United States (US), 15 require a solid foundation in the STEM fields (Eberle, 2010).

Unfortunately, in many countries the study of STEM subjects is often not a priority for students. Several social issues, to be discussed in this report, lead to a lack of understanding and enthusiasm in students, having a profound impact on the number of undergraduate students majoring in these fields. This lack of interest and enrollment substantiates the importance of improvements to STEM education. Without a good system, the number of professionals in STEM fields would be greatly decreased and the quality of life within different societies would be dramatically reduced.

1.2 STEM Education Around the World

Lack of STEM education is a worldwide issue, and many countries have little or no access to effective programs. According to the United Nations (UN), the world may be divided into three broad categories:

- Developed Countries. States that have a highly-developed economy and an advanced technological infrastructure.
- Developing Countries. States that, in comparison to Developed Countries, are still in the process of industrialization and have a lower standard of living.
- Least Developed Countries. States that have a low standard of living, low gross domestic product and suffer from structural obstacles to sustainable development.
The issues in STEM education faced by these three categories of countries are addressed in section 2.1. There is a vast divide between the extent STEM subjects are taught in developed, developing, and least developed countries. This discrepancy is unfortunate as some of the best minds in STEM may never get the opportunity to study them.

1.3 Mission Statement

To use space as a foundation for developing recommendations to improve the quality and accessibility of STEM education for all by embracing creativity, collaboration, and critical thinking.

1.4 A Vision for STEM Education through Space

The vision of this report is to provide a set of recommendations and product examples that will lead to a future STEM education system that evolves in accordance with societal needs, and which helps learners become intrinsically motivated to study within an intercultural and multinational environment. This vision allows for unique individual development and the practice of working together for the common good of humanity to coexist, both on Earth and in space.

Space brings students to the very frontier of human knowledge, where the deepest and most exciting questions are posed, and where new, innovative, creative, and artistic ways of thinking are required to solve them. Space delivers excellent applications for all the STEM disciplines and it promotes ways of thinking that are currently lacking in today’s STEM education. The implementation of space-related materials in STEM education allows students to learn from hands-on activities and stimulate their curiosity and creativity. This is why space should be used as an enabling medium, as it works both as a tool to educate, and to inspire. Historically, space projects and activities have produced a number of humanity’s greatest achievements in grand scale exploration projects, scientific discoveries, international cooperation, and technological advancement. Space, therefore, provides an enabling medium to improve STEM education systems the world over.

Space-related content is believed to be an excellent motivator for STEM education because it:

- appeals to students of all ages;
- inspires and motivates creativity;
- develops curiosity and critical thinking;
- is interdisciplinary;
- appeals to both genders and promotes equality;
- promotes International and cross-cultural cooperation; and
- strives for a common, thriving future.
Within this vision is the creation of educational products that will focus on primary and secondary curriculum, yet inspire all ages, children and adults alike. In addition, all the motivational items listed above are addressed. Also emphasized in the report’s products is the need to have a global appeal so that developed, developing, and least developed countries are all taken into consideration. Lastly, high accessibility at low cost was a factor in the products.

1.5 Organization of the Report

The team divided the report into chapters dealing with various aspects of STEM education, STEM and art, and how space can contribute to STEM education. Chapter 2 provides context information on STEM education worldwide: the current status of STEM education in selected countries, the social issues associated with STEM education, and teaching and evaluation methods. In Chapter 3, the team discusses the importance of integrating art into STEM in order to create a comprehensive science, technology, engineering, arts, and mathematics (STEAM) program. Chapter 4 describes a means for space to bridge societal gaps, such as those caused by economic, cultural, or geographical situations. This chapter also describes several potential product-based solutions and potential future strategies that can be globally applied to improve STEM education using the space theme.

This report concludes with recommendations for developing, improving, or changing the current STEM curriculum by making it more interdisciplinary and collaborative with space as the primary influence for achieving this goal. The conclusion highlights the ability of space to change current global inequalities. Using space to promote STEM education increases global creative thinking and open-mindedness, allowing for tomorrow’s leaders to have the skills to make the changes necessary to achieve a brighter future for all.
2 THE CURRENT STEM SITUATION

To use space as a tool to improve the quality of STEM education worldwide, it is important to first understand the current STEM educational process and its shortcomings. It is also important to note that not all countries have reached the same achievements in terms of education and space depending upon their degree of development and their social, cultural, and economic differences. In all aspects, STEM education needs to be more accessible to students and teachers worldwide.

This chapter discusses the international context for STEM education, the potential social issues that are met by various countries, and the current teaching and evaluation methods. Each section provides recommendations for future improvements that are outlined in Chapter 4, covering the strategies and potential solutions.

2.1 World Discrepancies in STEM Education

Not every country has developed expertise in STEM fields. For example, countries involved in space activities at the beginning of the Space Age have experienced a high level of development based on a strong, STEM-based academic foundation. There are differences in how each country and culture views the importance of education, and STEM education in particular.

This section will review the current situations of STEM education in the three UN categories of countries presented in the Introduction. For examples of the STEM situation in some specific countries, please refer to Appendix A.

2.1.1 Developed Countries

The education model introduced in developed countries at the time of the Industrial Revolution had the clear intention to prepare children to be part of the mechanized system of work. The structure of the curriculum and the methods of teaching and discipline were closely related to the operation of a factory. The education system has changed very little since then, despite major developments in technology and society during this period. The world has been experiencing an exponential development of technology, but the education model has not followed that technological development. Today, some nations are living in the Knowledge Age, with high technology, new concepts of communication, and sharing of information, but the education model remains the same as two centuries ago (Toffler, 1980). This time delay between the development of technology and education contributes to the observed decreasing interest in STEM.

Most developed countries have some degree of space interest and industry, which may benefit from local expertise in STEM subjects; however, just over half of students in developed countries consider studying STEM subjects (Lenovo, 2011).
The top reasons cited by students for not pursuing STEM careers are lack of confidence in their abilities, and too much required work/schooling. The global image of STEM disciplines is often negative and elitist, as will be discussed in section 2.2. Developed countries are facing stalled interest and participation in STEM subjects, thus compromising future competitiveness. STEM education is indeed critical for creating the workforce that any technology field, including the emerging commercial space industry, will need to succeed.

2.1.2 Developing Countries

Developing countries have large discrepancies in levels of technological advancement, and do not face the same economic, stability, and/or cultural issues.

In those countries with rapid market development, such as China and India, education has a strong financial incentive. For example, the MacArthur foundation (2012) found that “...one additional year of education adds about 10 percent to a person’s earnings...” and the Center for Universal Education (Brookings, 2011) noted that “...no developing country has sustained high rates of growth without investing heavily in educating its young people.”

By contrast, some developing countries with moderate or slow market development noticed a decreasing interest in STEM fields. Despite this disparity, they have sufficient technological and economic growth to eventually meet the UN Developed Country category.

2.1.3 Least Developed Countries

The conditions in least developed countries are far from the conditions in developed countries. Education may be considered a luxury in these countries where other primary needs are not satisfied. A recent UN Report entitled, “The Millennium Development Goals Report 2012” (UN, 2012) outlined the achievements made in least developed (and some developing) countries based on goals agreed upon by world leaders in the early 21st Century. One of the goals of Millennium Development is to increase school enrollment of girls (UN, 2012). Achievement of universal primary school education is of great importance because the lack of education limits opportunities for people later in life. With respect to STEM education, not many statistics have been found in the literature, although the UN Millennium Development Goals Report 2012 (UN, 2012) did mention that the global primary school completion rate recently reached 90%, compared with 81% in 1999.

The United Nations Educational, Scientific and Cultural Organization’s (UNESCO’s) strategy is to provide targeted assistance to least developed countries. Its actions include promoting quality education and providing policy advice and building capacity in science and technology. For example, there is a science and technology plan of action for Africa, in which UNESCO will contribute to the implementation of the following activities:

- capacity building in science policy;
- science and technology education; and
- establishment of an African Virtual Campus to address the shortage of qualified science teachers (UNESCO, 2011).
2.2 Social Issues in STEM Education

STEM education worldwide is impacted by social issues including: disparity between genders, cultural and societal aspects, and limited access to educational programs. These issues apply to varying degrees in different countries and tend to create social gaps (also referred to as social stratification) based on economic situations. Space has been identified as a potential way to close social gaps by improving STEM education. This section investigates the reasons behind the variation in the quality of STEM education in different societies and countries.

2.2.1 The Gender Gap

Being a girl remains a powerful barrier to education despite the concept of human rights (UNESCO, 2010). Although progress toward gender parity has generally been rapid over the past decade, the STEM fields are still lagging with respect to gender equality, in terms of wages, opportunities, and education. Women have made strides in fields such as the social sciences and education, but there is not a single country in the world where parity has been reached in STEM fields. Technology industries and scientific research are still predominantly male professions around the world.

Gender disparity is highly dependent on a country’s development category. In least developed countries, many girls do not have the same access to school as boys do. Many developed countries have made tremendous progress and have achieved approximately a 50/50 gender balance in education. Even in these cases, the women are underrepresented in the STEM fields.

In the United States, for instance, only one out of seven engineers is a women, and there has been no increase in STEM jobs for women since 2000 (Beede et al., 2011). In France, as stated by the French Women & Science Association, only 27% of the engineering graduates are women, whereas this number barely reached 7% thirty years ago (Femmes et Sciences, 2005). In China, women account for about one third of the overall scientific and technological workers (China Association for Science and Technology, 2009).

This discrepancy probably exists because women are less likely to study a STEM field and, if they do, they are more likely to drop out of school than men (Chen and Thomas, 2009; Griffith, 2010). Several factors play into the lack of interest and discouragement of girls in STEM education, including stereotypes, cultural aspects, and the lack of role models and peers.

2.2.1.1 Cultural Aspect and Stereotypes

There exists an unconscious bias that science and mathematics are typically masculine fields while humanities and arts are primarily feminine fields. STEM studies are often described as difficult, logical, and rigorous, which are stereotypically considered to be male traits, while women are said to be more artistic and communicative. These stereotypes are likely due to cultural factors as they have not been shown to have a biological basis. Regardless, these stereotypes deter girls from pursuing mathematics and science, and reduce their confidence in these fields (Butler, 1983; Femmes et Science, 2005).
Early exposure to STEM greatly increases the chances of students pursuing STEM fields (Griffith, 2010); however, stereotypes influence how children are raised. For instance, in some cultures boys are more likely to play with toys that develop their mechanical and problem solving skills, and as a result, are cultivated for careers in science and engineering. Meanwhile, girls tend to play with toys that facilitate creativity and nurturing, encouraging them toward the role of care-giver later in life. This link between women and familial obligations persists even after university graduation (Butler, 1983; Liang and Li, 2010). Women are less likely than men to be employed in STEM fields, and in many countries there is a noticeable difference between the average salaries of men and women, favoring the men (Beede et al., 2011).

### 2.2.1.2 Lack of Role Models and Peers

Studies have shown that students are more likely to select careers when they can identify with a role model in that career path. Further research has shown that the success of this strategy is enhanced by the use of gender-matched models (Butler, 1983; Buck et al., 2008). This is particularly true for the influence of female leadership on adolescent girls’ career aspirations and educational attainment, whatever the culture or environment may be (Butler, 1983; Beaman et al., 2012).

Although the number of women has been steadily increasing, most STEM teachers are male and their classes consist mostly of male students. Since same-gender teachers are important as mentors, female students may be discouraged by the limited number of female faculty members in STEM education (Asworth and Evans, 2001; Carell et al., 2010). The number of female STEM graduates also impacts the graduation rate of other female students (Griffith, 2010).

### 2.2.2 Limited Accessibility Issues

This section discusses other factors, namely financial, social, geographical, and environmental, which might impact accessibility to education. Although the problems in developed and developing countries differ, there are similarities concerning children’s access to STEM education.

#### 2.2.2.1 Financial aspect

Financial aspects are often linked to the quality of the education received. In developed countries, the high-ranked and private universities are often prohibitively expensive, leaving graduates with high debt (Poirier et al., 2009). This high cost can deter people with the potential to become teachers or researchers in STEM fields.

In developing countries, the relative cost of public universities can be prohibitive to a large portion of the population because of higher poverty rates. The Organization for Economic Co-operation and Development (OECD) has found that this phenomenon is not limited to developing countries, but is most serious in the least developed nations (OECD, 2009). It is often the case that the wealthiest obtain a better education than those poorer than them. This results in an ever-widening social stratification (Liu, 2005). In poorer homes the lack of books
and other materials, as well as under-educated parents, can result in weak scholastic performance (OECD, 2009).

Another side of the financial aspect is the lack of opportunities after graduation. Some developed countries experience brain drain, leading graduates to emigrate due to the lack of local prospects and a perceived abundance of opportunities abroad (Hanson, 2008). A strong national space program can inspire local populations to choose STEM fields, and then remain in their respective countries after graduation. The brain drain phenomenon is not seen in all developing countries; in India, research opportunities, job benefits, and wages have significantly improved over recent years (Spacemart, 2012).

2.2.2.2 Cultural and demographic aspects

Ethnic minorities in the US, such as Hispanics, African-Americans, and Asian-Pacific Americans, are generally underrepresented in STEM fields despite constituting an increasing proportion of the American population. Cultural factors may play an important role in this discrepancy. For example, Hispanic students generally favor shorter studies to avoid debt, and remain close to home (NACME, 2011). Even in countries without identified minorities or ethnic groups, cultural and religious beliefs strongly impact education and career choices. In certain extreme cases, girls can be physically prevented from going to school. Also, in some indigenous cultures, elders believe that STEM subjects compete with traditional knowledge, placing STEM education in conflict with cultural values (Lu, 2007).

2.2.2.3 Geo-political aspects

In least developed countries, schools in remote areas might not receive sufficient funding, or can even be physically inaccessible because of poor infrastructure. With correct infrastructure and training, teleconferencing may help schools in these remote areas. Developing nations tend to have less stable governments and societies, making it difficult to attract and retain teachers. Similarly, high crime areas in any country can hinder the establishment and operation of schools and the attraction of high quality teachers (Lowell and Findlay, 2001).

2.2.2.4 Family aspects

Sewell and Shah (1967) stated that “Children of higher social-class origins are more likely to aspire to high education and occupational goals than children of lower social-class origins.” The level of education of a parent will greatly affect the educational ambitions of their children. Parental expectations and cultural beliefs also heavily affect children and influence their career choices as they grow up. In China, some parents put a great deal of pressure on children to learn arts rather than STEM as a matter of prestige (Liu, 2005). In response to this parental pressure, the educational system and human resources in STEM fields are being updated and improved (Guo, 2011).
2.3 Teaching Methods

Many different resources are available to help children learn. Generally speaking, today’s formal learning takes place in a classroom with a teacher educating the students using lectures and assignments. This traditional approach is outdated and there have been attempts to update it. Among the suggested improvements are inquiry-based learning and alternative schools. The following sections describe these methods as well as their limitations.

2.3.1 Inquiry-based Teaching

In an effort to understand the current approaches being employed in schools, anonymous surveys were sent to school teachers around the world. The teachers were asked about the teaching materials they currently use to teach STEM subjects, the difficulties they encounter, and the ways that they felt space can contribute to help them teach STEM subjects. Twenty-nine responses were received from teachers in North America, France, South Africa, China, and Japan, representing teachers of primary through secondary education.

The first trend was that, regardless of grade level, hands on activities are the best way for teachers to approach STEM subjects with their students. From this survey (Flood 1, 2012), it seems that “. . .the more visual and hands-on the activities the better.” This demonstrates the current trends in education toward inquiry-based teaching methods. In the last decade, many educational organizations have made strides in implementing the inquiry-based approach to STEM education (Fensham, 2008) (UNESCO, 2008).

Simsek and Kabapinar (2010) encourage students to “. . .describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and share their ideas with others.” When asked whether they have employed inquiry-based teaching techniques, the teachers polled (Flood 1, 2012) responded that they use these techniques and that “. . .they are more engaging and provide a more memorable learning experience for the students.” Teachers generally agree that inquiry-based learning is a more effective method than the more classical lecture-centric education.

There are four levels of inquiry-based learning as shown in Table 2-1. At level 0, the student is guided through the entire learning process from problem statement to solution by a teacher. At level 3, the learning is completely determined by the student.

<table>
<thead>
<tr>
<th>Level of Inquiry</th>
<th>Problem</th>
<th>Procedure</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 3: Open Inquiry</td>
<td>Student</td>
<td>Student</td>
<td>Student</td>
</tr>
<tr>
<td>Level 2: Guided Inquiry</td>
<td>Teacher</td>
<td>Student</td>
<td>Student</td>
</tr>
<tr>
<td>Level 1: Structured Inquiry</td>
<td>Teacher</td>
<td>Teacher</td>
<td>Student</td>
</tr>
<tr>
<td>Level 0: Confirmation / Verification</td>
<td>Teacher</td>
<td>Teacher</td>
<td>Teacher</td>
</tr>
</tbody>
</table>

Inquiry-based learning can be very effective when used appropriately (Gee and Wong, 2012). Students’ performance scores correlate to their perceived exposure to inquiry-based education techniques. Scores increased across all countries in relation to the students’ perceived exposure to models in STEM teaching, but decreased as the amount of independent student
investigation increased. This suggests that inquiry-based learning techniques are beneficial to student success only when proper instruction and guidance are given by the teachers (Simsek and Kabapinar, 2010). When designing new programs for classroom use, it is therefore important for the educator to ensure that the program falls into Level 2 of Table 2-1 in order to achieve maximum impact.

2.3.2 Problems Faced by Today’s Teachers

The teachers surveyed (Flood 1, 2012) were also asked about difficulties they encounter when teaching STEM subjects. The teachers identified two major roadblocks that prevented them from effectively teaching STEM: Student attitudes toward STEM, and the lack of quality teaching resources.

Teachers indicated that their students’ biases toward STEM subjects are that they are “. . .only for the ‘smart’ kids [and] unnecessary.” (Flood 1, 2012) It is very difficult for teachers to inspire and educate young people who have already decided that science is too difficult or boring. Whether this negative bias is due to their parents or their peers, it can significantly influence their future career choices. A separate anonymous poll of 38 participants at the 2012 ISU SSP (Flood 2, 2012) found that 37% of the respondents reported being strongly influenced by their parents. The results are presented in the word cloud in Figure 2-1 below. It is clear from this poll that parental influence is a major contributor to student success in STEM subjects (also mentioned in section 2.2.2.4).

![Figure 2-1: SSP12 Participant STEM Motivations](image)

Per the teacher survey (Flood 1, 2012); 50% of teachers reported a lack of quality resources. They believe the resources available to them are often outdated, age inappropriate, or of sub-par quality; however, a tour of major space agencies’ websites reveals 185 space-related
programs for teachers (NASA, 2012) (ESA, 2012) (Science in School, 2012). The resources desired by teachers are therefore available if they can be found. The problem is that teachers are unaware of the online resources, do not believe the material is adequate, or do not have the money and time to find and deploy the material.

2.3.3 Alternative approaches

Non-traditional education refers to any type of educational activity that is not classroom-based. Different kinds of schools offer various types of non-traditional education.

The most notable examples of non-traditional education take place at so-called alternative schools. The 19th Century New Education system (Ullrick, 1994 and Neil 1969) focused on student happiness and allowing students to learn at their own rate. This contrasted the more mechanistic system from the Industrial Revolution that focused on standardization and conformity. Today, over 1,000 independent Waldorf schools (alternative schools) exist worldwide at primary and secondary levels (IAWE, 2012).

Independent schools are independent from government funding and have freedom in the choice of teachers and curriculum. The Summerhill independent school, founded in the United Kingdom (UK) in 1921, allows children freedom to attend lectures of their choice. The students gained self-confidence, and oftentimes a high level of expertise in their chosen subjects (Ainsworth, 2000).

Charter schools, or schools of choice, are another form education reform resulting from a study in 1988 (Budde, 1988). These schools are publicly funded but have more freedom, as they set their own rules and curriculum. Teachers are given the freedom to adapt their teaching methods to specific situations and geographical locations. Despite the initial idea that such schools would improve student’s results, accredited studies have shown varying results between schools. This reform has been implemented in many countries, including but not limited to the US, New Zealand, UK, and Canada.

The idea behind these schools was to improve student performance and results on evaluations, however some the accredited studies in the US have so far shown inconsistent results. According to Stanford Center for Research on Education Outcomes (CREDO) report (CREDO, 2009), more than 80% of charter schools have shown no better, or even worse, results compared to the traditional schools. On the other hand, individual reports, such as the recent report on Noble Street Charter Network (Spielman, 2012), claimed great results for the charter school, such as a student graduation rate of 90%, compared to a rate of 54% in traditional schools nearby. Significant wait lists demonstrate parents’ high interest in charter schools.

Finally, home-based learning is an approach to educate children at home while following a certain type of given curriculum. Results on the effectiveness of home-based learning still need to be analyzed and verified. Home-based education offers lower costs per student, which could be a big advantage for parents opting to teach their children using this method. While home-based education is legal in many countries, it is illegal in other countries where public education is mandatory.
2.4 Evaluation and Metrics

The comprehensive evaluation of student learning and teaching abilities is an important and often overlooked aspect of the development of STEM educational content. This evaluation is essential for three reasons: it allows teaching materials to be improved over time; it quantifies the benefit provided for the costs of developing and delivering content; and it allows standardization and concentration of effort on the most effective materials and approaches. This section first provides insights into the international discrepancies in STEM curriculum and STEM teacher trainings. The current student, teacher, and curriculum evaluation techniques are then reviewed. Recommendations on improved methods of assessing student learning and their attitudes toward the material they study will be provided in section 4.5.

2.4.1 International Evaluation of STEM Education

Three studies were conducted by the International Association for the Evaluation of Educational Achievement’s during 1964, 1981-82, and 1995 to understand the effectiveness of instruction in various countries, mainly in the field of mathematics, but also in other subjects, such as science, based on the evaluation of student performance. These studies have been called First International Mathematics Survey, Second International Mathematics Survey, and Trends International Mathematics and Science Study (TIMSS). The studies considered information on a large number of factors fundamental to teaching and learning, such as curricular frameworks, textbooks, classroom organization, and societal and parental support. The evaluation focused mainly on 13 and 17-year-old students as participants. The number of countries participating in the evaluation varied with each study, the maximum being 42 countries in the TIMSS (Medrich and Griffith, 1992) (Fowler and Poetter, 1999).

Conceptualized in 2000, Programme for International Student Assessment (PISA) is a system of international assessments that evaluates the students’ capabilities in reading, mathematics, and science literacy. The study is mainly focused on 15-year-old students. Apart from the core subjects, PISA also assesses the students’ capabilities on general or cross-curricular competencies such as problem solving. The emphasis by PISA is on functional skills the students acquire by the end of compulsory schooling (OECD, 2009).

Many disparities in educational curriculum and evaluation across different countries in the world exist. It is important to consider the disparities when evaluating student performance as well as the curriculum.

In general, European and Asian nations have better student learning methods compared to the rest of the world. These countries have focused their curriculum and assessment system on skills such as problem solving, conducting investigation, analyzing and synthesizing data, teamwork, communication, and independent learning (Hammond-Darling and McCloskey, 2008).

Smaller (less populated) countries have adopted the system of national standards, and may have national level tests for evaluation. Finland, for example, uses local assessments to evaluate its national standards, but has a voluntary national assessment only at the final grade level. Larger nations, such as Canada, Australia, and China, have standards developed at the
state level, along with an assessment system that is a blend of state and local assessments. The advantage of this system is that it allows for more effective teachers to be recognize/promoted, and because of high-quality local assessments, the consistency in scoring can be maintained (Hammond-Darling and McCloskey, 2008).

The US does not have national standards for curriculum and evaluation. Each state manages its own curriculum and evaluation system, and some states delegate the responsibility for this to the individual districts. The nature of this decentralized system has resulted in wide variation in curriculum as well as performance expectations across the country (Vernille, 2002).

Many disparities are also observed in teacher training and education worldwide, having an influence of the quality of student learning. Teachers must be aware of the different ways a student might learn or absorb information, in addition to being cognizant of emerging teaching techniques and new resources available.

In least developed countries, it was found that the lack of teacher education and development presented a large challenge in meeting the increasing demand for better quality teachers. To combat this challenge, Africa has established a teacher education program that focuses on training teachers. This program is still currently in its developmental stage (The African Virtual University, 2005).

In some developing countries, distance learning programs for teachers, which are an alternative and cost effective way to deliver training and courses, are also offered. The goal of distance learning is to upgrade or qualify teachers through the use of certification courses (Bof, 2004).

Teachers from developed countries are able to receive varying levels of education in their profession, not necessarily specific to STEM subjects, ranging from undergraduate degrees to post-doctoral studies. Regardless of a teacher’s level of education, professional courses throughout his or her career are considered to be of utmost importance in order to develop skills and stay up-to-date on trends and teaching techniques (Mizuno, C., 2004).

The quality of teaching provided to students has an impact on the quality of education being received (International Alliance of Leading Education Institutes, 2008). Teachers must work in a demanding and complex environment. As such, teachers must be committed to continuous learning and a strong professional identity. In some countries, teachers are expected to lead by example, providing a moral education to their students in addition to the learning curriculum (TRIPOD, 2000).

In order to ensure that teachers are able to adapt to changing environments and student needs, and have the strength of character to be able to set the right example for students, some educational institutions have rigorous requirements for a person to qualify for entrance into their programs. However, despite the entrance requirements and the training/education received, teachers should still be examined regularly to see whether or not they are succeeding in providing the education required (Wang, A.H., Coleman, A.B., Coley, R.J., and Phelps, R.P., 2003).
2.4.2 Evaluation of Students and Teachers

In this section, the present systems of student and teacher evaluation are briefly discussed. A retrospective on former evaluation techniques and their evolution is given in Appendix B.

The task of learning cannot be divided into separate objectives and be independently evaluated (Eisner, 1985). Evaluating students by an artificial division prevents students from grasping large-scale concepts using the bits of information they are given. According to Eisner, in order to nurture students to be problem solvers and critical thinkers, modern education systems must implement an evaluation-driven curriculum. Eisner states that these skills cannot be learned by routine practice, and concludes that modern evaluation of both students and teachers should incorporate the full complexity of classroom events.

Traditional evaluation consists mainly of exams and written tests (Armstrong, 1996). Evaluating only by exam grades does not present equal opportunities to all students to show their capabilities.

A comprehensive evaluation should consist of both direct and indirect methods. Direct assessment methods require students to show their knowledge and sometimes solve problems that they have already encountered, while indirect methods require students to reflect on their actual learning. The tools for direct assessment are exams and writing assignments, while indirect methods might include interviews with the students and parents, observing class interactions, and surveys. Relying on a single evaluation method will only reveal a part of students’ learning and achievements (SUNY Orange, 2012).

Furthermore, each student experiences school slightly differently than their classmates, and possesses a different set of skills. For this reason, using an objective scale to score all students is not only unjust toward the students, but cannot provide sufficient information about the entire spectrum of learning achieved by the student. To reach a desirable outcome, both direct and indirect assessment methods should be used.

2.4.3 Evaluation of the Curriculum

According to Worthen and Sanders (1987), curriculum evaluation is “. . .the formal determination of the quality, effectiveness, or value of a program, product, project, process, objective, or curriculum.” (pp.22-23) Curriculum evaluation is necessary because it allows students and teachers to track their own performance and constantly improve their teaching methods. Additionally, it provides a point of comparison among other curriculum, and enables decision makers to validate their decision of using one curriculum as opposed to another.

The conventional method for assessing the effectiveness of a curriculum is evaluating the students before and after exposure to the material (Hammerschmidt, 1994). A more comprehensive approach may also include surveying leaders and teachers about the usability of the material, the extent to which students absorbed the material, and the level of class engagement. Parents can also provide invaluable input that in many cases cannot be accessible through teachers. Parents in many cases know their children better than the teacher and can provide more detailed feedback.
There are two types of evaluation: formative and summative. Formative evaluation is usually used to attain information to improve a curriculum, and is performed while forming the curriculum. It includes one or more of the following: identifying the target audience (a specific age group), defining the needs and goals (required skills, knowledge, and experience), and how to achieve these goals (Worthen and Sanders 1987).

In contrast, summative evaluation is when data is collected after the curriculum has been used and then compiled into useful information. Qualitative interviews, direct observations, and document analyses can be used together with quantitative data.

Ultimately, when criticizing an education program, the following concerns should be addressed:

- Does the new curriculum deliver the desired knowledge about the subject?
- To what extent does the new program encourages students to think on their own, and effectively apply problem solving techniques to real-world problems?
- Can each student express his or her own personality (such as their interests, strengths, or skills)?
- What are the effects of the new curriculum and their implementation on classroom events (including better student participation and noticeable teamwork)?
- Participants’ reaction to classroom events (Were teachers organized? Did students enjoy?).
- What improvements can be made to the curriculum, which responds to feedback from the students, teachers, and administrators?

These questions emphasize the process of learning and the overall classroom experience of the target audience. This leads to the conclusion that seemingly attractive, but oversimplified, solutions should be avoided.

2.5 Discussion: The Need for Improved STEM Education

Although countries around the world have reached different levels of economic development, many are facing STEM education issues. In most developed countries, there is a general disinterest in STEM disciplines, increased by the boring reputation of STEM fields and prejudicial stereotypes. In many developing countries, student interest in STEM is higher but equality is far from being reached, oftentimes with male and wealthy students having easier access to STEM studies. In least developed countries, STEM education is often poorly developed and exclusively reserved for a small portion of the population, while the remainder barely has access to basic primary education. It is, therefore, recommended that new products for STEM education make attempts to include developing and undeveloped countries.
As identified above, women and minorities are often discouraged from pursuing STEM studies because of a variety of issues including:

- familial or social background influences;
- cultural, religious, or ethnic issues;
- societal stereotypes; and
- accessibility issues due to rural or remote areas.

These can vary in importance depending on the country’s category. When promoting STEM education, the team recommends that these underrepresented groups be accounted for. Improving accessibility is also recommended for new products in STEM education.

Current teaching methods were also reviewed in this chapter. Teachers face numerous issues today, including the lack of motivation of many students and their disinterest in STEM fields. Alternative teaching methods have been discussed but have not yet been proven to be more efficient than traditional teaching methods. Teaching through hands-on activities leads to a better understanding of a subject, as students actively decipher concepts instead of memorizing them. It is a much more effective way to educate, but if students are left alone with the activity they may not reach their goals. Therefore, teachers must be present to guide students through these activities while allowing them to discover concepts on their own.

A number of international studies have been conducted to understand the effectiveness of instruction in various countries mainly in the fields of mathematics and science. PISA has been found to be effective in international assessment of student performance and teaching, and address the measures of cross-curricular competencies. It is important to consider the differences in teacher education and evaluation methods across different countries in the world. Traditional student evaluations used in most countries provide only a narrow view of what students have learned. More comprehensive feedback systems are needed for student and teacher evaluation. This will improve the curriculum and classroom experience, facilitate standardization of education, and ultimately provide each student with a learning experience tailored to his or her individuality.

Predefined ideas often persist in societies, leading to a gender gap even in countries where education is equally accessible between the genders. To improve the status of STEM education, it is important to move past outdated methods and misconceptions, toward an improved system. The recommendations in this report strive to make STEM education more global, equitable, affordable, creative, and attractive.
3 STEM TO STEAM: INCORPORATING ART

The marriage of art and science is a beneficial arrangement to artists as well as STEM professionals. Art can make STEM subjects accessible and enjoyable, bringing science into a wider social realm while endowing it with a human touch. Art brings humanity to STEM, and STEM to the general population. Art is a link between the technical experience and the personal experience. Many countries, especially developed countries, are now focusing on STEM as an essential component of national innovation. Recently, there has been an initiative by STEM educators to transform STEM into STEAM. STEAM not only supports interdisciplinary collaboration, but a bold, fresh method of innovative thinking.

In this time of exponential technological growth, new questions, problems, and challenges need to be answered, solved, and met. New ideas and new concepts are needed to make this possible. The inclusion of art and design-driven thinking in STEM is a useful approach to apply to STEM problems. To begin, art must first be defined for the purposes of this report.

3.1 Definition of Art

The traditional notion of art represents anything derived from the right-brain dominated creative individual, while the STEM process to solutions tends to be viewed as a left-brain dominated logical procedure. Art is seen as the opposite of rational analysis and avoidance of the unknown. Art tends to be associated with informality, intuition, and an ability to go beyond usual boundaries. A balancing act emerges when these opposing characteristics meet. There are several ways this can occur:

- as an action analyzing or synthesizing the problem;
- as a descriptive experience;
- by approaching the solution through a logical or random thought;
- by using sequential steps instead of using intuition at each moment;
- by objective/subjective opinion; or
- by dividing the problem in individual parts or treating it as a whole.

A combination of both action and experience is required for a well-considered result or a well-balanced individual. Focusing on this balance, two definitions of art come into play: art as a creation process and art as an experience.

3.1.1 Art as Process

Art can be considered a divergent, creative, or unstructured process that produces different ideas and new paradigms. It represents lateral, non-linear, abstract thinking, and exhibits relationships between seemingly unrelated subjects. While this can be applied directly to a piece of fine art or to an experience, it is helpful for the purposes of this proposal to highlight the use of art as a general design process that can be applied to space-driven STEM education.
French designer Remy Bourganel focuses on the function of art as a design framework. By his definition, the process of art is not limited to the creation of a traditional fine art product such as a painting or a piece of music; it can be applied to any creative synthesis activity (Bourganel, 2012). A major component of any design process is logical decision making. One example of this type of decision-making process, also applied by Bourganel, is abductive reasoning. Abductive reasoning can be described as guesswork attempts to link a premise and an outcome, and has been compared to someone trying to guess the code on a lock:

“When the tumblers are lined up properly, the lock unlocks. “The ah-ha!” moment is identical to the unlocking, as different idea combinations come together in sync to make a reasoned thought.” (Leuch, 2012)

Bourganel’s emphasis on abductive reasoning as a mental process is a form of inference previously outlined by logic theorist Charles Peirce as “...the only logical operation by which to introduce a new idea.” It is noted as the most appropriate beginning to the scientific method and is best served when followed with rational deductive reasoning (Boy and Brachet, 2009).

Boy and Brachet, 2009 states that abductive reasoning has been used successfully in the field of engineering for a long time when practiced by goal-driven, creative, and competent technical leaders. At a 2008 conference on risk taking and abduction, organized by the Air and Space Academy, it was noted that abduction and creative reasoning, combined with reasoned choices, was successfully used by Airbus’ engineering and flight tests when they designed and developed fly-by-wire technology and glass cockpits. This same type of intuitive, skilled process can be applied to both space and STEM as an initial tool in the creation of innovative devices; therefore, in defining art as a design process, it is useful to include the activity of generative abductive reasoning.

The Schools of Excellence Model [(SoE)] in Scotland is an example of how this definition of art can be applied to improve space-driven STEM education. (SoE)² was a proposal from the Designing Transformations Project. As noted by Marie Fairburn (2011), “[Skills Development Scotland] invited partners Robert Gordon University and Gray's School of Art to review the existing (SoE)² model, which used inspirational and iconic [space] partners to encourage young people to consider careers in [STEM]”. Fairburn continues “Designing Transformations led to a new model for a learning journey...” in which “Schools of Excellence arise out of an educational framework that uses broad themes, catalysts, or hooks such as Space, to engage students.”

Art was also applied to the Designing Transformations project through the process of visualization. Fairburn notes that mapping ideas through the use of diagrams “…facilitates creativity in the development stage of the [(SoE)²] model…” thus “…enabling the development of big and bold ideas across the learning stages.” (Fairburn, 2011)

By applying this same technique to the relationship of art and STEM (See Figure 3-1), visual form is given to the relationship, revealing its iterative nature. Art as a design process leads into an artistic experience or supports the creation of a technical system. These systems or experiences provide feedback that inspires new processes. It may be deduced from this model
that improving one part of the system will improve the whole. The second part of this system, art as experience, is defined in the next section.

![Figure 3-1: The STEM-Art Relationship](image)

### 3.1.2 Art as Experience

Art is often perceived as the feeling experienced by an audience as a result of a creative object or product. In the case of a traditional form of fine, literary, visual or performance art, such as a painting, a book or a musical composition, the receiver would be a person experiencing the subjective response to the object or product. More modern examples include objects such as multimedia video or sensory-rich games. Many intangible idea-based products also produce a subjective emotional response, and should not be discounted in the definition of art. An encounter with a narrative, metaphor, or simulation can be described as an artistic experience.

The annual international *Humans in Space Youth Art Competition* is an example of a space-driven STEM project that employs experience-based art as a tool for creative communication. Adopting the classical and more contemporary popular definition of art objects, the form of art requested in the contest specifically refers to "Visual, Literary, Musical, and Video Art." Art in this case is defined as a creative communication of ideas that attempts to answer the specific space-related question: “How will humans use science and technology to explore space, and what mysteries will we uncover?” (LPI/USRA, 2012) In this scenario, it is the communicated answer that creates a sensory-rich environment for space-driven STEM.

Art as an experience is not necessarily separate from art as a process. This is evident after taking a closer look at the long-term process and possible consequences of this youth art competition. The 2010 competition’s theme question asked: “What is the future of human space flight, and why is it important?” (LPI/USRA, 2012) Young people aged from 10-18 attempted to answer this question by producing tangible creative work. In turn, the judges and audience members were able to experience the young people’s views of space. Two of the contest winners in the overall art category exemplify how art processes and experiences can be related back to the STEM system. Inspired by current space technology, the students were
drawn to learning about alternative forms of propulsion. Students aged 17 (Austin Hess, *Electrostatic Solar Sail Animation*) and 15 (Ian Moffett, *A Journey with a Solar Sail: Solar Sail Solaris*) were intrigued by the idea of solar sails, and decided to design a mission for future human exploration. Advancements in technology inspired them to work through the design process while producing a video (NASA-Johnson Space Center/USRA, 2012). This process formed a product experience—producing the video—that in turn, communicated possible future uses of STEM technology. In this example, space studies inspired a creative experience for an audience that was able to feed back into the STEM system.

The experience of art is not a one-way channel. While an art object such as a sculpture or theater production can affect the audience, the audience can also affect a human performer. In the case of narrative art, the human performers share the experience. There is a deep level of learning from subjective experience that occurs when students engage in space-driven STEM projects that involve story-telling, theater, or simulations. An immersion that enables a student to experience something outside the boundaries of everyday life is a memorable event. The depth of the experience can change the perception of one’s view of the world. The Space Foundation Discovery Institute (SFDI) in Colorado has developed a program to create a better learning experience through the utilization of interdisciplinary technology-driven narrative simulations. Part of their STEM education outreach includes a simulated space mission operation center as well as a simulated Martian terrain laboratory. The foundation uses space-focused STEM along with art “…to help students apply difficult-to-see concepts of real-world simulations and be able to apply classroom learning to real world examples.” (SFDI, 2011) This type of narrative learning is synergetic. While students create, they are affected by learning experiences, teachers, and parents. This creates enthusiasm toward STEM-related matters in the community.

### 3.2 Art in STEM

As noted above, art can be defined as a design-driven creative process, an experience of an object, product, audience, or a combination of all. There are many tangible and intangible advantages of applying these forms of art to space-driven STEM. This section will outline three major benefits and cite examples of how they have been successfully applied in order to develop recommendations for future STEM product development. These benefits include: universal appeal, creative learning tools, and hands-on practical immersion.

#### 3.2.1 Universal Appeal

Art in its many forms is a phenomenon that crosses boundaries of culture, language, age, gender, and economic background. The value of this cannot be understated, and is a perfect complement to the global space industry. Art and applied creative design break boundaries that may not be broached by technology or engineering.

Chiaki Mukai, the first Japanese woman in space, used a Japanese traditional linked poem form called “Renga” in her second spaceflight mission aboard Space Transportation System 95 (STS-95). Her starting verse, which refers to microgravity, received a staggering 150,000 responses
from around the world. It is a testament to the power of art and its ability to speak to many people.

A “Renga” is one type of a traditional Japanese poem composed of lines linked by an idea and written by two or more persons. As one of the Tanka (Waka) poems, it is an unrhymed Japanese verse form with a fixed syllabic pattern, and has units of 5-7-5 as the first phrase followed by 7-7 syllables, arranged in that order.

In 1998, on her second spaceflight mission, Chiaki made units of 5-7-5 as follows:

Turn space somersaults,
As many times as you like,
This is weightlessness (Mukai, 2012)

There were 144,781 responses to these units from the Earth, including 489 responses from English-speakers. People who launched the 7-7 syllables ranged from 5 years old to 105 years old. Manami Tanno, a 10-year-old girl, wrote the response:

With a floating water-drop
Wish to play as “bouncing-ball” (Mukai, 2012)

Responses expressed wonder over the microgravity environment of space, appreciation of a precious Earth and its beauty, wishes to live and work in space, and dreams for future space exploration and the creative freedom possible when human beings are released from the burden of gravity. The wide appeal of this poem, bolstered by the inspiration of space, led to an increase in the motivation of children all around the world to study STEM subjects.

A leading figure who understood the universal appeal of art in relation to science is Qian Xuesen. Qian Xuesen was a key figure for both the US and Chinese space programs. He was involved in the United States effort to develop missiles to defeat the German V1 and V2 rockets while serving on the US Scientific Advisory Board during World War II. He later participated in the Manhattan Project, helping the United States to develop the atomic bomb. In 1955, he returned to China and devoted the remainder of his career to the Chinese missile and space
program. He was a well-respected leader of the Chinese aerospace program, helping to develop the Long March rocket, and the first satellite that was launched in 1970. He is widely regarded as the father of Chinese rocketry.

From Qian Xuesen’s letters, it is found that he loved literature and art from a young age. Qian’s own experience can be called a typical model of the combination of science and art. His major was science when he attended the affiliated middle school of Beijing Normal University, but he also studied painting. He was interested in playing the violin and writing essays. During his studies at Shanghai Jiaotong University he played trumpet in the school band. Qian Xuesen was fond of painting and calligraphy and had high appreciation for music culture as influenced by his wife, Professor Jiang Ying, who was a celebrated musician brought up in a European school. During his learning and working period at the California Institute of Technology, he also attended the American Art and Science Association. He said: "...in the association, there were scientists dressed in suit and tie, and there were also some artists dressed at random wearing long hair. Some ideas of the rockets were initiated when I was communicating with the artists." (Xinhuanet, 2007)

His communication with artists led to another act with universal appeal. Qian Xuesen not only admired art but was an inspiration for it: Arthur C. Clark named the spaceship Tsien after Quian Xuesen in the novel 2010: Odyssey Two (Nothaft and Kline, 2011).

Qian Xuesen is not only known for his contribution to art and science, but also to the necessary implementation of both fields in schools. In the article “Facing Qian Xue’s Sen’s Question”, Yao Mingqui notes that just before his death, Quian Xuesen asked the question “Why do our schools always fail to nurture outstanding talents?” (Mingqui, 2012) It is a brave question that emphasizes the importance of a well-rounded education.

### 3.2.2 Creative Learning Tools

Art as a creative process or experience can bolster STEM learning in many ways:

- it is a fun and interactive medium for science, making it accessible to a wide demographic of students;
- creativity is an intensive process, and submersion facilitates learning;
- through art, one can develop a personal or value-led connection to subject;
- art helps develop an ethical relationship to a subject, which gives it a meaning outside of the classroom;
- art is often a sensory-led process, which facilitates learning;
- opportunity for failure in creativity can create tenacity and an experimental mindset, while promoting lifelong learning skills;
- art sharpens and broadens communication skills; and
- art can be utilized as an educational feedback tool in place of, or in addition to standard grading methods, because it gives insight into the subjective minds of children.

Art is present in everything. It is present in the way humans perceive the environment as well as how they respond to it. It is essential for scientific study. By using art within STEM, the
scientific method for solving the problem being faced can be enhanced. Art can also help inventors or creators to make their creations more socially acceptable and useful for a broader group of clients and partners. A lack of creativity and fun may result when art is missing in STEM education or when it is considered a hindrance rather than a useful tool.

Dr. Jancy McPhee, Director of the Humans in Space Youth Art Competition, has noted some of the benefits of art as a medium for space-driven education. Dr. McPhee outlined that using art as a tool:

- helps educators to do a better job of teaching;
- increases excitement and dialogue about space;
- encourages dialogue about space between nations and generations;
- is a good way to figure out what youth are thinking through the portrayal of ideas; and
- educates people about space (McPhee, 2012).

Art is not only a tool for dialogue or internal insights. The Humans in Space Youth Art Competition promotes the union of scientific understanding and creative communication. This is outlined in the visual art judging criteria on the contest website, which promises bonus points if the artwork does not break scientific principles (LPI/USRA, 2012). Students are encouraged to combine creative expression within parameters, learning the valuable skill of creative thinking within scientific boundaries.

Art also serves as a powerful tool for societal change in this example. The Humans in Space Youth Art Competition facilitates social connections between youth and STEM leaders, promising to make the ideas of the participating youth visible to space exploration leaders worldwide. It gives global youth an opportunity to immediately shape the world around them, providing instant gratification and real-world validation of their learning efforts, which ultimately encourages learning. In its loftiest gesture however, it awards a special Inspiration Peace Prize to artwork(s) that “...best express(es) a vision of how cooperation in human space exploration can help create peace on earth.” (LPI/USRA, 2012)

The application of the creative process to STEM education is exemplified by design-led systems of education re-engineering. Creativity and innovative thinking complement logical, linear thought. In the Designing Transformations project, Fairburn (2011) wrote: “...design thinking [could] be applied across the spectrum of innovation.” A successful hacker model was developed to encourage accessibility to the project. The hacker or off-the-shelf ability to use existing resources and tailor the program to the specific objectives of a given school showed the type of adaptability born of creative thinking. Fairburn also noted that the (SoE)^2 pilot was not only creative but practical in its concept of using low-fidelity space simulations. Fairburn also pointed out that creative, intuitive thinking is a fundamental future skill that can be used “…to expand the toolbox of science and engineering today.” (Fairburn 2011)

3.2.3 Hands-On Practical Immersion

Successful hands-on learning is supported by the fully immersive environment that creative work often provides. The Victorian Space Science Education Centre is a good example of this method. Per their website (2012), primary school children are able to experience a Mars base
mission while being introduced to robotics, human physiology, microbiology, nanotechnology, and environmental science. The children immerse themselves like theater actors for the whole duration of the program in the roles of astronauts. Their interaction with their environment promotes problem solving, teamwork, communication skills, and leadership. The children are not the only ones being stimulated while on this experience; it also provides their teachers with a chance to learn about science teaching methods.

“The use of real life scenarios provides the link between the classroom and the real world, representing contemporary science that is meaningful to the students and relates to their lives out of school.” (Mathers, Pakakis and Christie, 2011)

These scenarios are based on an immersive environment that engages the children in space-related activities through the use of sophisticated computers and communications methods while learning cooperation and teamwork. The scenarios are separated between mission control and the Mars base. Mission control has the task to monitor the climate, the air, and water supply while coordinating the energy supply. The Mars base has other responsibilities such as water recycling and filtering, analyzing Mars soil, building electronic circuits, and extracting Deoxyribonucleic Acid (DNA) from organic matter. All these experiences help to build positive attitudes in the children toward science while also helping teachers to build confidence in their STEM teaching skills.

Another example of a creative immersion process using space as a hook is the Future City Competition, a US national competition for children in grades six through eight. The program is sponsored in part by “...the National Engineers Week Foundation, a consortium of professional and technical societies and major U.S. corporations.” (National Engineers Week Future City Competition, 2012) Children are invited to compete at schools to think, design and build a futuristic city using Electronic Arts’ SimCity™ 4 software. The students are required to take into account all the aspects of systems building, including power, waste, and water cycle management. In this scenario, children are immersed in solving a real-world simulated case. This hands-on, creative process allows the student to deal with a wide variety of actual issues that are currently faced in cities around the world. This marriage of hands-on immersion using a sensory-rich environment with real technical issues is supported by a space-related motivation. The first place team wins a place at Space Camp in Huntsville, Alabama (National Engineers Week Future City Competition, 2012).

Art is not only useful in team environments. It can also have a real impact on the private life of a single human being. An outstanding example of this phenomenon is Albert Einstein. Since he was not a very good student in school, his teachers recommended to his parents that they challenge him with some type of manual activity. He received a violin. Learning to play violin helped him to develop his abstraction capacities that were required to develop his famous photoelectric effect and general relativity (Brams, 2012). This was no isolated incident. Cognitive and brain science centers such as the Max Planck Institute, support the claim that music has a beneficial effect on the brain (Max Plank Institute, 2012).

There is a direct relationship between creative, immersive hands on activity and an increased abstract understanding capacity. This, along with universal appeal and a wide variety of
learning methods, contributes to a multitude of benefits that art can bring to the STEM community.

Figure 3-3: Albert Einstein
Image credit E. O. Hoppe [online]

3.3 Discussion

Space brings value to STEAM as an inspirational springboard, a multi-disciplinary driver, and an engine of universal questions. These questions can be developed and solved through STEM alone, but including art in the process/experience can be of great benefit to students, teachers, parents, and the wider community. New questions require new answers, which in turn require new concepts. Art is integral in turning the ideas, concepts, and dreams triggered by space into reality through STEM fields. The universal appeal, creative learning tools, and hands-on practical immersion that art provides are the perfect complement to space-driven STEM learning.

The team recommendations for future space-related STEM products:

- incorporate art as an experience; or
- incorporate art as a design process; or
- incorporate art as an experience and as a design process.
4 USING SPACE TO IMPROVE STEM EDUCATION

Taking into account the different issues in the previous section, this section will address the question: “What can space contribute to global STEM education?” There are several reasons space is a powerful tool to make STEM education more global, equitable, affordable, creative, attractive, and adaptable:

- Space is inherently borderless
- Space belongs to everybody
- Space activities are flexible
- As a powerful motivational tool, space pairs well with art
- Like art, space has universal appeal
- Space is a fast-growing and promising industry

Practically, societies cannot rapidly achieve a new education system based on these ideas. Nevertheless, some space-related activities or advertisements can be developed and oriented toward a more global audience to make an immediate impact. These actions will raise public awareness and interest in STEM and space fields.

This chapter discusses existing attempts to use space to improve the quality of STEM education and suggests new space-related products and evaluation methods. This chapter provides a list of recommendations for space-driven solutions to improve STEM education, which address the problems and requirements proposed in the previous chapters.

4.1 Space to Inspire

Space activities and achievements, especially human space exploration, have proven to be an exceptional source of inspiration. Examples such as the Apollo missions to the Moon, the creation of the International Space Station, exploration missions to Mars and beyond, and recent human space flight achievements by China, need little introduction or explanation. These achievements are catalysts that inspire us to dream about tomorrow and motivate us to pursue dreams.

Space also provides perspective, referred to as the “overview effect,” which is the experience of viewing the Earth from space. One becomes aware of the fragile nature and uniqueness of Earth. The continents are seen without borders and the insignificance of humanity’s conflicts and stubborn ideologies becomes clear.

“It has been said that astronomy is a humbling and character building experience. There is perhaps no better demonstration of the folly of human conceits than this distance image of our tiny world. To me it underscores our responsibility to deal more kindly with one another and to preserve and cherish the pale blue dot, the only home we have ever known.” - Carl Sagan, Pale Blue Dot: A Vision of the Human Future in Space (1994)
As discussed in section 3.2.1, the poem by Japanese astronaut, Chiaki Mukai, expresses the spiritual and creative freedom possible when human beings are released from the burden of gravity. Her poem helped make people more aware of the beauty and the preciousness of the Earth, and feel like they are connected to the planet. Space science and technology allow people to recognize how relatively small humans are in the universe, and the complexity of the environment in which humans live. Space can be used to stimulate cultural acceptance and to diminish stereotypes.

The ability of space to inspire has universal appeal that transcends age, gender, nationality, and culture, and should be used more effectively to be a force that acts on STEM education. One of the findings of this report, as presented in section 2.3.2, is that students often lose interest in STEM education because of the disconnect that exists between the STEM curriculum and its future applications.

Not only can space activities and achievements inspire the pursuit of STEM education, they can also serve as a means to keep the flame of motivation alive. Thus, space activities and achievements should be promoted vigorously to support STEM education. To achieve this goal, large sectors of the population should be familiarized with space activities and achievements. Familiarization is important because involvement of adults and communities is crucial in supporting children’s educational choices.

Many efforts have been implemented to increase space awareness, such as establishing space science and technology museums, holding exhibitions on space achievements, and presenting lectures to youth about people and events relevant to space activities. Despite these efforts, space programs and related initiatives do not always reach the entire population, especially in remote areas and socially and economically disadvantaged areas. A disconnect exists between space activities and public opinion, which strongly affects the potential for space to inspire. To address this disconnect, the media can play an important role in advertising both space activities and their contributions to STEM education. Charismatic speakers can help popularize current and future space science on television, such as Bill Nye: The Science Guy, Neil DeGrasse Tyson, Carl Sagan, and Jacques Cousteau (Favier, 2012; Niederstrasser, 2012).

4.1.1 Space as Inspiration to Address the STEM Gender Gap

Women are beginning to be represented in the traditionally male dominated STEM professions. Research has shown that students are more likely to select careers where they can identify a role model. The combination of these two factors can explain the lower involvement of women in STEM subjects (Butler 1983).

The professional achievements of women in the space field can serve as inspiring examples for girls. Female leadership is a positive influence on adolescent girls’ career aspirations and educational goals, regardless of culture and environment (Butler, 1983, and Beaman et al. 2012). It is important to have more role models representing women in STEM fields, and to emphasize their participation. Female astronauts, especially those from different nationalities and cultures, should be encouraged to promote STEM education around the world. Japanese astronaut Chiaki Mukai’s outreach activities (Figure 4-1) are excellent examples of how STEM
can be promoted to a great number of people through space-related activities. She inspires women and promotes the arts around the globe through poetry.

![Chiaki Mukai, First Female Japanese Astronaut](image)

**Figure 4-1:** Chiaki Mukai, First Female Japanese Astronaut (NASA, 2012)

Effective mentoring by role models to STEM students throughout their lives is important to provide perspective and support (Poirier et al., 2009). Mentoring is especially important as a source of guidance for children or students who do not have strong family support structures (Hardman, 2012).

As previously stated, a higher percentage of females in a field will encourage more women to join the space industry. This principle also applies to underrepresented ethnic groups (Griffith, 2010).

### 4.1.2 Space as Inspiration to Address Cultural Issues

The history of international collaboration in space programs can be a tool to promote understanding and communication between different cultures. Ethnic minorities can be sensitive to the presence of role models and peers in their chosen occupations (Griffith, 2010). Increasing the ethnic diversity of astronauts and space engineers is important to engage minority groups that are current underrepresented in STEM fields.

Some national space programs garner significant attention by sharing their culture with the world, as exemplified by the ‘Fly your cook into space’ program (Mukai, 2012). With this program, people were given the opportunity to transform their favorite recipes into astronaut meals, which were later flown on the STS-65 mission. This special program reached a wide
range of people, from children to the elderly, as well as many different cultures. It is important to trigger a spark in children’s minds, but also to gain attention from adults, as they play a major role in children’s educational choices. Making adults aware of space activities and space jobs might influence them to support their children to study STEM subjects, whatever their background or culture. This encouragement can improve STEM education for current and future generations.

Clustering is a concept that can ensure ease of communication for schools located in various areas, and is one tool to enhance academic excellence. Collaboration between partner schools in different countries through space-related student competitions, as suggested in section 4.4.4, can be used to stimulate cultural acceptance, international collaboration, and knowledge transfer between different nations.

### 4.2 Space to Develop

Since humanity’s first explorations into space, nations and international organizations have recognized the ongoing need for the STEM fields. This section describes interdependence and synergy between a country’s space program and its national economic development. A country’s ability to improve its economic and social situations is dependent upon its ability to develop and expand its capabilities in science and technology (Hauser and John, 2009). In addition, the establishment of new national space capabilities is part of the overall process of technological learning in support of national development (Wood and Weigel, 2011). Nevertheless, delving into any type of national space presence, whether it is space applications, satellite communications, or research, is an expensive undertaking. At a national level, only countries that have economic stability and financial means are currently in space. Not all developed or developing countries have a national space presence, but it should be noted that international collaboration and cooperation can give developing and least developed countries access to some space activities and technologies.

To establish national space programs, the Space Foundation (Hauser and John, 2009) recommends that developing countries should focus on programs that provide direct benefits to its society, consider national collaboration for the development of space programs, and create national space policies and legislation.

Despite over 40 years of US dominance in space activities, and the important presence of Russia and Europe, other countries are now beginning to emerge as major space sector players (Matthews, 2011). With China paving the way, nations from South America, Africa, and the Middle East are making their way into orbit.

In Africa, Nigeria created its National Space Research and Development Agency to develop space science and technology that would provide the country with socio-economic benefits. In 2003 Nigeria bought a remote sensing satellite and paid for the training of Nigerian engineers (Wood and Weigel, 2011). After a decade focused on building up its local technical capabilities, Nigeria built its own satellite, which launched in 2011. With respect to additional socio-economic benefits, Nigeria’s Earth Observation satellites do monthly crop monitoring, which
socio-economic needs. The South African Space Agency is also developing, and plans to perform Earth observation, space operations, space science, and space engineering.

India, through the Indian Space Research Organization (ISRO), now has the capability to build and launch geostationary satellites and lunar spacecraft. Since 1975, the country has been developing its expertise in space technology-related areas and has developed its own capabilities for Earth observation, tele-communication, weather satellites, and related applications for national development.

South Korea’s space agency, the Korean Aerospace Research Institute, was created in 1989. In 1993, South Korea launched its first locally-built Low-Earth Orbit satellite, training its local engineers within the same project. Additionally, South Korea’s first astronaut and ISU alumnus, So-Yeon Yi (Figure 4-2) brought great pride and inspiration to the people of South Korea.

![Figure 4-2: South Korea’s First Astronaut So-Yeon Yi](NASA, Expedition 16 Image, 2008)

In partnership with the European Space Agency (ESA), in 1991, the UN initiated annual Workshops in Basic Space Science for developing countries. The purpose of these workshops was to emphasize the UN’s increased attention to education and research in space science and technology. More recently, the UN plans to launch UNESCOSat, its first satellite to promote international cooperation and a shared world heritage. The US$5m satellite will have the mission of discovering whether human feces can be used as fuel (Hakeem M. Oluseyi, 2011).

Despite efforts of international organizations and individual countries to expand humanity’s knowledge of science and technology in the interest of increasing space activities, there are still some countries that are unfamiliar with what space programs and space involvement can do
for them and for the improvement of their economies (Abubakar, 2008). An institution such as an international space agency would be beneficial to the major existing space players that often have issues with raising funds; for the non-space fairing nations, it would be a chance for their citizens to get involved in exciting space activities.

Space represents a good opportunity to start with a solid educational base and promote STEM education. Some countries that do recognize the beneficial capabilities of space are developing their STEM expertise through national STEM education initiatives.

### 4.3 Space to Educate

The idea of using space in education is not new. Many national space agencies devote some resources to developing educational material that can be used by interested students and teachers. Such activities are discussed in the following section (4.3.1). This report also identifies extra-curricular space activities conducted by other organizations and societies (section 4.3.1). All of the activities described in this section are not only beneficial for expanding knowledge about space and attracting a wider audience to space, but they can also raise awareness of STEM importance and attract students to STEM disciplines. Moreover, this project proposes including space in the official curriculum, while also using existing extra-curricular resources.

#### 4.3.1 Space Agency Contributions to STEM Curriculum

The contributions of space agencies around the world in the promotion of STEM education are extremely valuable. They provide high quality material and expertise that is unmatched by other sources. The international context in which these agencies operate may facilitate the interaction between students from different countries. The necessity of international cooperation to face imminent challenges can be effectively conveyed to children. Space agencies should be considered as a natural reference point in the search for benefits that space activities can provide to education. The programs, extra-curricular opportunities, and supplementary materials that the major space agencies provide to teachers, students, and communities in support of education will be briefly reviewed in this section. As they have more developed outreach programs, the following agencies will be reviewed in detail: NASA, ESA, JAXA, and ISRO. Even though most of the addressed agencies are located in developed areas, the focus on ISRO provides insights into the educational potential by space agencies in developing countries. The education approaches of other space agencies also are briefly addressed.

#### 4.3.1.1 NASA

In the US, NASA’s daring expeditions have pushed the boundaries of humankind’s understanding of the universe, and our place in it. The technologies developed by NASA have provided benefits all over the world. None of this could have been accomplished without a workforce possessing a solid STEM background.

NASA is committed to ensuring the continuation of these technological breakthroughs, and to helping develop the next generation of STEM professionals. NASA has always allocated money
in its budget toward educational activities and materials. NASA continues to pursue three major goals as part of their education program:

- strengthen NASA and the future workforce;
- attract and retain students in science, technology, engineering, and mathematics; and

NASA implements hundreds of programs for all levels of students every year with successful results. The resources provided are meant to inspire and educate students about space, and to facilitate an easy transition into a STEM-related career. An important advantage is the very attractive image that NASA has created through Hollywood productions and the video game industry. Students have access to information through numerous multimedia channels, which may motivate them to pursue one of the STEM fields.

### a. Educational Materials

The NASA education program provides thousands of resources on their website, with links to many more, which is accessed by millions of users every month. This website also provides “. . . *popular educator guides downloaded more than 20,000 times per month.*” (NASA Education Activities, 2012)

The NASA website is conveniently divided into a section for educators and a section for students, so that all the users are easily directed to the most suitable area. The available resources are organized according to product type, grade level, and subject. The provided material does not focus explicitly on the autonomous teaching of each STEM subject as currently implemented in schools, but offers the student a multidisciplinary approach. In other words, the material is not used to teach mathematics, physics, or engineering in a traditional manner, but helps the students to develop critical thinking and problem solving skills by providing practical examples of STEM-related careers. The available material for educators is then complemented by trainings and classroom lesson models supervised by NASA experts such as the NASA Aerospace Education Services Project.

NASA’s Jet Propulsion Laboratory (JPL) understands the impact that effective outreach can have on a space program, and how to use this to foster education. Exploratory missions to the Moon, Mars, and other extra-terrestrial bodies create curiosity among students. Materials based on these missions serve as good teaching tools for use by parents and teachers alike to kindle interest in STEM fields. A prime example is Curiosity, the Mars Science Laboratory (MSL), mission scheduled to land on the surface of Mars in August 2012 (Figure 4-3). JPL has realized the potential of this mission to create interest and motivate students to engage in STEM education. JPL has used Curiosity to provide innovative materials for teachers to use in classrooms to make STEM education more interesting, interactive, and artistic. Using these materials, students are introduced to many STEM fields, including robotics, planetary sciences, and life sciences.
Additionally, NASA has organized the NASA's Mars Rover Curiosity Landing Educator Conference for the weekend leading up to the landing. According to their website (2012), this conference will "Bring the excitement of Mars exploration to your classroom or other educational environment with standards-aligned, STEM-based, hands-on activities, and take-home image-rich learning materials."

Providing these types of materials, and organizing these types of conferences, encourage teachers to use space to improve STEM education.

b. Programs

STEM education can particularly benefit from programs that:

- connect the three communities of primary and secondary students, college/graduate students, and professional experts; and
- engage and inform teachers, students, and their families and communities (Allner et al. 2010).

To accomplish this, particular efforts must be targeted to underrepresented and underserved students.

Besides achieving these goals, NASA programs are designed to fit in the framework of the 5E learning cycle (Engage, Explore, Explain, Extend and Evaluate), which helps students build their own understanding from experiences and new ideas (NASA eClips, 2012).
The different opportunities provided by NASA vary significantly in duration, complexity, and required funding, so that different needs may be adequately addressed. A complete list of the available programs can be found at the NASA website (NASA Education Program Opportunities, 2012). Some of these activities provide interaction between classes and NASA experts, who can give lectures or perform hands-on activities in the classroom. Opportunities for internships, scholarships, fellowships, summer research, team competitions, and after-school activities are also available. The implementation of these programs relies on the resources and facilities available at the different NASA centers. Each of these centers has its own Education Office, which is responsible for the organization of locally hosted programs.

4.3.1.2 ESA

According to the agency website (ESA, 2012):

“since ESA was created, more than 30 years ago, one of its most important tasks has been to inform the public about the latest advances and discoveries in the space field, and to develop programs that will inspire young people to pursue careers in science and technology [...] The aim is to help young Europeans, aged from 6 to 28, to gain and maintain an interest in science and technology, with the long-term objectives of contributing toward the creation of a knowledge-based society and ensuring the existence of a qualified workforce for the Agency that will ensure Europe’s continued leadership in space activities.”

Similar to the structure adopted by NASA, ESA provides both educational material and programs. The programs dedicated to supporting teachers are led by the European Space Education Resource Office (ESERO). ESERO provides educators with specially developed materials, lesson plans, fact sheets, and comprehensive education kits. It defines focused activities for teachers and different age groups of students. The office is also a point of contact for teachers in primary and secondary schools through dedicated workshops and meetings. ESERO has headquarters in different European Member States that promote the achievement of their specific educational needs. Scholarships and attendance opportunities in international cooperation activities are also provided. The complete list of the available projects is available at the ESA website (ESA Education, 2012).

ESA has added environmental studies to the topics traditionally addressed by STEM subjects. According to their level of knowledge, students from high schools and universities can take part in all aspects of activities such as the creation of a small satellite mission. They can use the facilities provided by ESA for hands-on projects or collaboration and can participate in competitions organized by the agency to facilitate the interaction between groups of students from different nations.
4.3.1.3 JAXA

According to the agency website (JAXA, 2012):

“Space is an eternal theme in the search for the origin of human beings and the universe and is one of the best subjects for educational activities. JAXA has given high priority to educational activities to nurture the human resources of those with an interest in things like space, the Earth and life, and these will bear fruit for future Japanese and international space development, space science and aeronautical technology. JAXA is providing a study environment for students from elementary and junior high school age through to university and graduate school level, and various programs for instructors who teach these students.”

JAXA educational action is coordinated to some extent with that of NASA and ESA, although some differences exist. The available material (divided into support for formal and informal education, space school for families, and international activities) does not focus exclusively on STEM, and its management is coordinated by a single Space Education Center. This centralization allows the direct involvement of educators and experts from the major research facilities throughout Japan in the development of agency programs. As a result, space subjects and materials are better integrated into the existing curriculum instead of being proposed as extra-curricular, volunteer-based activities.

4.3.1.4 International Space Education Board (ISEB)

Besides their own educational programs, different space agencies have agreed on the development of a larger coordination. ESA, NASA, JAXA, the Canadian Space Agency (CSA), and CNES, formed ISEB in 2005. The board aims to share educational practices and to promote worldwide interest in space and STEM subjects (ESA, A further step..., 2012). Among the projects already implemented by ISEB are:

- the creation of a network of ground stations for improving communication capabilities between operators and student satellites (Global Educational Network for Satellite Operations);
- the development of a mini-constellation of CubeSats providing communication capabilities to areas without infrastructure (Global Experimental Orbital Initial Demonstration);
- better access for students to attend international space conferences;
- and various internship programs (ESA callprop, 2010).

The results of these agency coordination efforts are reflected in the similarities between the materials they offer, though some differences still exist.

4.3.1.5 ISRO

In India, space technology has been used for education in two different ways. Space technology is used as a tool to enable education, and the topic of space is used as content for educational outreach programs. Education and training in STEM subjects, emphasizing space and its role in
societal development, have been an integral part of the Indian Space Program since its beginning.

a. Educational Program

Similar to agencies in developed countries, ISRO provides training programs for students and teachers, as well as workshops, exhibitions, science fairs, and quiz programs (ISRO Education and Training Portal, 2012). These programs are created to enhance science and technology education, and to improve the outreach in space-related activities for societal development. According to the available data, about 350 participants including students, school teachers, university faculty members, and professionals are involved in these annual programs. The support of the major research institutes and programs overseen by the Department of Space facilitates the involvement of high school and university students in current activities. These programs include the Indian Institute of Remote Sensing (IIRS); the Center for Space Science and Technology Education in Asia and The Pacific; and the National Natural Resources Management System.

ISRO has developed an Education Portal, (ISRO, 2012) and has a special section for school education programs in science, mathematics, and English. This portal hosts educational videos on many topics in these subjects, and can be accessed by school teachers and children. Posters, brochures, and books on prominent achievements in space by ISRO are posted there for use as material and tools for teachers to engender curiosity in children about space, and to motivate them to take up a STEM field.

ISRO’s Sponsored Research (RESPOND) program encourages academic researchers and students to get involved in collaborative research. RESPOND provides financial support for “. . .research and development activities related to Space Science, Space Technology, and Space Application to academia in India.” (ISRO, 2012)

b. Tele-Education

Tele-education has been a great resource for India’s development. This technology connects the underserved rural areas to the leading urban educational institutions. The Educational Satellite (EDUSAT), launched in 2004, is the first thematic satellite dedicated to education and is actually used to “. . .provide one-way TV broadcast, interactive TV, video conferencing, computer conferencing, and web-based instructions.” (ISRO EDUSAT Programme, 2012) “More than 30,000 classrooms have already been provided connectivity through the Edusat network.” (ISRO tele-education, 2012)

4.3.1.6 Other Space Agency Education Approaches

Other developed and developing countries are also committed to education, but the level of dedication is different in each case. This section will briefly review their current attempts to use space for STEM.

Brazil has been working on increasing its space knowledge and human resource development through its Science Without Borders program. By the end of 2014, Brazil intends to send almost
three hundred students to foreign universities to increase its number of science and engineering graduates. With this newly-established local expertise, Brazil intends to adapt and develop its space technologies to customize its national requirements (Wood and Weigel, 2011).

One of the greatest sources of inspiration for space education in Israel is Ilan Ramon, the first Israeli astronaut, who was killed in the Columbia accident in 2003. His wife Rona established the Ramon Foundation in 2009, with one of its goals being to promote educational excellence in Israel. As a result, the foundation is supporting many space-related activities for children during and outside of school time (Roman Foundation, 2011).

Another notable activity in Israel’s approach to involve space in the curriculum is the growing number of high schools that have a space studies program. In such programs, students can start learning space-related topics and take part in hands-on exercises such as building a rocket and conducting research on nano-satellites. In parallel to the formal studies, students have the opportunity to meet experts from Israel’s space industry and visit aerospace factories (Blizovski, 2006). These workshops and extracurricular activities for high school students encourage teamwork skills and enhance students’ self-esteem. Figure 4-4 shows a program run by ISU alumnus Daniel Rockerberger that is currently operating in three Israeli schools. The students design experiments that are sent to the International Space Station (ISS), and then they receive and analyze the results. This is a unique opportunity for young students to perform an educational scientific experiment in space, thus increasing the enthusiasm of thousands of students.

**Figure 4-4:** Israeli Students Develop Experiments for the International Space Station

In Romania, the space program is coordinated by the Romanian Space Agency (ROSA). One of the most inspiring figures for young students is Dumitru Prunariu, (Prunariu, 2012) Romania’s sole astronaut and Chairman of the UN Committee on the Peaceful Uses of Outer Space. Every year, ROSA organizes several educational programs and competitions to promote space among elementary, secondary, and high school students. ROSA recently became a full member of ESA, and is currently funding a growing number of doctoral theses. A number of educational programs are planned for the future, including partnerships with NASA to increase awareness of STEM and space; however, significant changes will require a higher degree of government support.
Canadian students learn about Canada’s accomplishments in space from a young age. They are inspired by astronauts such as Roberta Bondar, Marc Garneau, Julie Payette, Bob Thirsk, and Chris Hadfield; along with technology such as the Canadarm and Dextre. Many of these students are eager to pursue careers in STEM fields in the hopes of one day being able to join the CSA or even NASA and add to these national accomplishments. Another of Canada’s contributions to space is less well-known but perhaps even more important: approximately 80% of all satellites include Canadian products (ComDev, 2012). This is something that students may not know about early on, but this is the industry in which many space-inclined STEM professionals in Canada will end up working.

The Chinese National Space Administration (CNSA) does not have a clearly developed educational program; however, educational events have been implemented by the agency throughout the years. Two examples that have garnered media interest are the CNSA 2006 events, during which Hong Kong high school students were invited to Beijing to attend a space education program at Beihang University. The Hong Kong youth aerospace lovers’ education and training camp started in Beihang University in 2007 to increase Chinese public awareness about the Chinese Lunar Exploration Project. CNSA also launched the Chang'e Lunar Project publicity campaign for science education (Beihang University News Center, 2006) (China Lunar Exploration Project Centre, 2007).

The Russian Federal Space Agency (ROSCOSMOS) also provides education support through the Yuri Gagarin Cosmonaut Training Center. The ultimate educational goal of the center is to engage the general audience with space programs and achievements through hands-on activities and workshops. Visitors are encouraged to take part in different phases of the cosmonaut training, to visit exhibitions, and to talk to experts in the space professions. Teaching material and interactive educational content for kids are also delivered on the web site, and student participation in space related conferences and competitions is facilitated by the center.

4.3.2 Other Extra-Curricular Space Activities

Extra-curricular learning involves a wide range of activities that do not follow a standard curriculum-based educational framework. In the context of space-related learning, this chapter investigates space camps, space applications (apps), hackathons, international workshops or projects, astronomical and planetary societies, and the famous Google LunarX Prize.

Examples of space camps conducted across both developed and developing countries for age groups from four to five (4-5), from six to eighteen (6-18), and older, are numerous and include:

- Space Camp (US Space and Rocket Center, Huntsville, Alabama, USA)
- Space Camp for Interested Visually Impaired Students (US Space and Rocket Center, Huntsville, Alabama, USA)
- Space Camp India
- Amicale Space Camp (Noordwijk, The Netherlands)
Such courses bring students into the international environment, enabling them to learn about space material that is often underrepresented at schools. At the same time, students are challenged to solve problems in a new and interesting environment. Experiencing space launch forces in simulated environments, talking to astronauts, and experiencing amazing views of the Earth or the ISS in Image Maximum (IMAX) theatres, can be life-changing experiences. Creating more of these types of space camp experiences internationally would reach a wider audience, though it must be taken into consideration that presently they serve only a limited number of students, who usually come from wealthier or middle-class families. It would be beneficial to try to extend the reach of space camps to a broader audience from a wider financial demographic.

While hackathons are a very popular way of learning and networking for computer engineers, they involve a growing number of other disciplines, including space. The International Space Apps Challenge (ISAC, 2012) is an example of a recent space app hackathon, with over 2000 participants in more than 25 places on Earth and in space (specifically, on the ISS). The participants were challenged in different disciplines, from software development through open hardware, and citizen science to data visualization, all of them being space-related challenges. This is an excellent example of promoting STEM fields using space. The Team has concluded that increasing the number of similar events in the future will help to foster STEM education.

Astronomical and planetary societies and clubs, such as the Planetary Society, American Astronomical Society, and Ursa Astronomical Association, have existed for a century or longer in many countries. They share the goal of increasing space awareness and engaging people in active exploration. In this context, the Google LunarX prize (XPrize, 2012) is an example of the new projects that specifically promote STEM fields through space. There is a separate section on the Google LunarX prize site that is devoted to education. From this, it can be realized that modern industrial giants are aware of the STEM problem and are getting actively involved in solving it.

There is a wide variety of material available from various sources on the Internet. For a list of many of these, refer to Appendix F.

4.3.3 Introducing Space to the Curriculum

The aforementioned space-driven activities are useful in promoting STEM and motivating students; however, these activities are limited and have not yet achieved the goal of significantly increasing the number of STEM students and professionals.

Despite the efforts of space agencies located in developed countries, these countries are currently experiencing a severe crisis in the number of students pursuing careers in the STEM fields (National Research Council of the National Academies, 2011). Such a trend seems to indicate that the available activities are “...completely inadequate to impact the national educational system.” (Jeff, 2002) The effectiveness of educational programs should be tested through the long term tracking of the students and of the teachers that participate in these programs. Such a survey would reveal if the involvement in these projects effectively directs students toward STEM careers, and whether or not they help in achieving excellence in these
fields. Unfortunately, information on the long-term tracking of participants is not available yet, as the first evaluation program targeted to this scope was established in 2007 (NASA edass, 2007). Regarding educational material provided by the space agencies, communication of those materials is the most urgent issue to solve. It has been shown that teachers who are exposed to the material tend to use it in their lectures; however, many are not aware of the contribution that space activities can give to STEM education (Jeff, 2002).

In the production of an educational program targeted to enhance student interest and performance in STEM fields, the space agencies located in developing countries may now benefit from the experience of existing projects. They can then contribute at the same time with original new products suggested by their own cultural uniqueness. The synthesis between these two approaches may lead to the definition of a more effective educational program.

Valuable achievements in science, mathematics, engineering, and technology have been proven to positively impact economic growth (National Research Council of the National Academies, 2011). Least developed countries can benefit from the educational material provided on the Internet by the major space agencies. Tele-education products may be designed to reach remote areas, and this can encourage these countries to take their first steps toward space activity.

The long-term existence and global spread of the traditional education system shows its necessity and applicability. At the same time, the numerous alternative schools that have existed for more than a century worldwide show that people feel the need to change the traditional system. The rationales behind the alternative schools reveal weaknesses in the traditional system that many people want to correct, such as the mechanistic teaching methods. Unified and serial education groups, with test-based evaluation methods, are not seen as fair to children who express themselves differently. The gap between the approaches of current traditional and alternative classroom methods suggests that a happy medium approach between the two can offer the best results.

Inquiry-based learning techniques are beneficial to student success since they are more engaging and provide a more memorable learning experience as compared to traditional methods. For such reasons, this report recommends increasing the use of guided inquiry-based teaching methods. Many supporters of alternative schools also favor such methods. The results of inquiry-based teaching are against the traditional method only in the cases when the teaching is guided (section 2.3). For this reason, a new education system should still have teachers as the facilitators for students learning; however, living in the Knowledge Age, it is critical for the students to develop abilities to search, find, and evaluate relevant information themselves. The ability to quickly absorb and analyze new information, with a critical eye toward the reliability of the received information, is a necessary skill in any society undergoing rapid change. Faced with numerous other demands on their time, attention, and money, students are showing little interest in the seemingly difficult STEM subjects. STEM is not considered cool. Part of the vision of this report is using space to show the youth that STEM is worth their time. Space, and the potential for amazing off-world adventures, can be combined with images of exploration, high technology, and impressive new space ships to show everyone that STEM education fields are a cool and attractive option. The commercial space industry is a
newly emerging field, and a strong STEM background will be required for new professionals in this field. Using space in schools as an interdisciplinary coupling of different subjects is necessary for the future. One of the complaints from critics of the current education system is that a granular and artificial split of the learning process to isolated subjects is constraining to students’ learning. On the other hand, space can serve as a great source for abductive reasoning, allowing students the chance to form and test their own theories related to exploring this new frontier (Sir Ken, 2009).

In the suggested improvements involving space-related materials, extra-curricular space-related content and activities may be used as an alternative or complementary way to enhance students’ interest and performance in STEM education. To make those resources more efficient than they currently are, an approach similar to JAXA’s should be applied: collaboration should be established between the education policy makers and space agencies. Such collaboration could solve issues of teachers not being informed about or trusting the quality of the offered material. More accessible and global space-related activities should also be made available, and should be included more regularly into standard school curriculum. The following sections suggest improvements on existing products, as well as new products using space-related content could be incorporated.

### 4.4 Potential Product Based Solutions

The products and solutions presented in this chapter are designed to fulfill the mission statement as defined in section 1.3 to “...use space as a foundation for developing recommendations to improve the quality and accessibility of STEM education for all by embracing creativity, collaboration, and critical thinking.” They also attempt to take into account the new concepts of communication and sharing of information used in the current Knowledge Age. The research from Chapters 1 and 3 have been summarized into the recommendations in Table 4-1 to guide the development of these products. A matrix cross-referencing these recommendations with the solutions outlined in this section can be found in Appendix F.
This report proposes the following new space-related STEM educational products:

- Workshops
- Space Cycle Game
- Utilizing World Space Week
- On-Orbit Student Competitions
- Textbook Updates
- Khan Academy Extension
- Video Outreach

These products are each applicable to several target audiences, and apply to a different medium. For more information on this, refer to Appendix A.

Additionally, a solution to bring space-related topics into student evaluations is included.

### 4.4.1 Workshops

The four workshops described below are designed to integrate different grade levels of students, where the senior students act as mentors to the junior students. Specific content can be added, as needed, to meet curriculum requirements at each grade-level. These workshops have different difficulty, cost, and time requirements so schools can select the most feasible solution for their situation.
These workshops meet the following recommendations from Table 4-1:

- Includes developing countries
- Available and designed for all cultures and genders
- High accessibility with low costs
- Supports guided, hands-on learning
- Improve student perceptions of STEM being too difficult
- Can be used as an introduction of why it is interesting and important
- Provides a system for evaluation and feedback allowing improvement
- Has a formal process to assess student learning and attitude
- Incorporates art as an experience and a design process

4.4.1.1 Workshop #1: Looking Up and Down

Activity: Kite-launched Photographic Platform
Difficulty: Easy
Cost: Low
Timeframe: Short

Summary: Looking Up and Down is an easy, low budget, and quick workshop to encourage students to engage with each other at different age levels by building and launching an aerial platform to gather remote information such as aerial photographs. The main benefits to the students and teachers are: promoting collaboration between students at different age levels, which encourages learning by teaching; teaching fundamental concepts about space flight; introduces remote sensing; the construction of the kite is a hands-on activity; and low cost and low difficulty makes it easy to implement.

Goal: To encourage students to build and launch an aerial platform that can be used to gather remote information such as aerial photographs. This can be used as a gateway activity to introduce fundamental concepts relating to flight, and to facilitate collaboration and communication between students of different age groups. This low cost, easy to implement workshop is meant to get students to look upwards, while examining the information captured by an aerial platform pointed downwards.

Concept: Senior students are tasked to design and build a kite that can be used to launch an aerial platform for the purpose of taking photographs from a higher altitude. They are given a set of requirements (materials to use, size/weight of camera, altitude to reach) and a set amount of time to design and build their kite. Other students at various age-ranges are tasked to assist the build/launch process where possible. Including younger students in the process creates a learn-by-teaching approach and provides continuity for the project in future years.
Educational Topics (relative to student experience level) to include:

- History of human flight
- Theory of flight
- Construction materials (kite design, material strength, durability, weight)
- Concepts of photography (ground vs. elevated)
- Weather and wind
- Mathematics - calculating elevation, object size by examining photographs

Execution: Senior students (17yrs) are paired with junior students (15yrs) who will assist with the building process. Middle School students (12yrs) are tasked with monitoring the launch day weather, potential obstructions, layout, and sequence of kite launches. Elementary students (8yrs or younger) may be included in the process by soliciting names for the kites, design ideas, creating reports about the success or failure of their favorite kites, or by creating artwork. It is important to involve students at several grade levels to foster a sense of community and ownership of the science involved.

Possible Modifications: Use of a weather balloon and sensor package (such as a smart phone or camera) could be used to gather information from a higher altitude and larger area. Other schools or groups could be enlisted in a competition.

4.4.1.2 Workshop #2: Nature and Us

Activity: Environmental Monitoring
Difficulty: Low
Cost: Low-Moderate
Timeframe: Long

Summary: Students are tasked to deploy a weather monitoring platform or series of platforms to monitor the weather conditions in the local area. This activity is time consuming but has a minimal cost and a low level of difficulty for the participants. This workshop teaches the students about producing a final product for launch and makes the students aware of the environment and the health of their planet. This project can be used to facilitate discussion on atmospheric activities and weather patterns, and tie that information to actual scientific measurements collected from the local area or satellite platforms. Students should realize that weather is a global phenomenon with local effects.

Goal: To encourage students to think about the environment and the health of their planet. This project can be used to facilitate discussion on atmospheric activities and weather patterns, and tie that information to actual scientific measurements collected from the local area or satellite platforms. Students should realize that weather is a global phenomenon with local effects.

Concept: Students are tasked to deploy a weather monitoring platform or series of platforms that are used to monitor the weather conditions in the local area. Cost can be tailored to meet budget requirements by selecting either a basic temperature and rainfall gauge or a full weather station. Older students can collect weather data and create their own weather
forecasts, collaborate with other schools, and share their knowledge with younger students to achieve the learn-by-teaching objectives.

Educational Topics (relative to student experience) to include:

- Water cycle
- Weather systems, wind and storms
- Sensors and scientific measurements
- Satellite weather monitoring platforms
- Weather forecasting difficulties

Execution: Older students are tasked with deciding what measurements are required and then deploying the sensors. Younger students will be included in the process according to their ability using tasks such as: choosing the locations for the sensors; naming the weather stations; or providing ongoing care and upkeep for the sensors. Collected data can be compared to that from existing weather stations, and related to serious weather events. Involving students of all age groups creates a greater sense of ownership in the project.

Mentor Options: Local meteorologists and weather professionals could guide or mentor students by presenting classroom material or acting as ongoing collaborators.

Possible Modifications: Expanding the network of weather sensors will give a clearer picture of the local weather conditions, and online collaboration with other schools offers opportunities to study the weather on national or international scales.

4.4.1.3 Workshop #3: Touching the Clouds

Activity: Rocket Launch
Difficulty: Moderate-High
Cost: Moderate-High
Timeframe: Short

Summary: Students design and build model rockets to meet specific goals and requirements. Immediate goals of project management, rocket design, and mission requirements are linked to space-related lessons from other disciplines (age and subject appropriate). A local competition that includes students of all age groups builds excitement and interest, and fosters a sense of community and ownership of the project. This project requires specialized instructor knowledge and a larger budget; however, rocket launch activities are very engaging and memorable for the participants.

Goal: Model rockets are designed and launched in a community effort that invokes images of space and space exploration by encouraging students to look up and to aim high. This activity can be used to facilitate discussions on history, current uses, and the future of rocketry.

Concept: Students will design and build model rockets with specific goals and requirements such as carrying an egg, sensor package, or camera. Immediate goals of project management, rocket design, and mission requirements are linked to space-related lessons from other
disciplines (age and subject appropriate). A local competition that includes students of all age groups builds excitement and interest, and fosters a sense of community and ownership of the tasks involved.

Educational Topics:

- Rocket history, crewed/uncrewed space flight
- Rocket design, flight, control and mission parameters
- Environmental sensors or payload design (such as CanSat, parachutes, cameras)

Execution: Senior students (17yrs) design a rocket mission that meets requirements and construct the rocket with assistance from junior students. Middle School students (12yrs) would be responsible to monitor weather conditions, check launch site, provide a countdown, track, and recover rockets after launch. Elementary students (8yrs or younger) can be enlisted to name the rockets, report on their favorite designs and create artwork to share with others.

Mentor Options: Local space agency, university, or rocketry clubs for creative input and guidance

Possible Modifications:

- Have staff members build a rocket
- Involve other area schools in a competition
- Allow senior students to compete in a larger competition, and mentor junior students in building their own designs

Follow-up: Examine and analyze data collected, compare experiences and discuss design improvements for future missions. Include historical lessons and space celebrity personnel to make the experience more relevant to the participants.

4.4.1.4 Workshop #4: Beyond Earth

Activity: Using Astronomy in Education
Difficulty: Low-Moderate
Cost: Low-Moderate
Timeframe: Short-Ongoing

Summary: A simple, low budget project where the students will examine the Earth as a planet and place it in context of the solar system and universe. Senior students cover advanced subjects and research options, and use their knowledge to teach junior students. Younger students cover age-appropriate concepts within their own classes using existing astronomy teaching material. The project is intended to help students understand the scale of the Earth, the solar system, and the universe.

Goal: To encourage students to think on an astronomical scale rather than a town or country scale. Discussing the machines that have been sent into space and the future opportunities to
explore beyond the Earth will help students expand their understanding of the Earth on an astronomical scale.

Concept: Students will examine concepts relating to Earth as a planet, and place it in the context of the solar system and universe. Senior students can cover advanced subjects and research options, and use their knowledge to teach junior students. Younger students can cover age-appropriate concepts within their own classes using existing astronomy teaching material.

Educational Topics:

- Earth (atmosphere, ecosystem, gravity, magnetic field)
- Satellite orbits and human-made objects in space (such as ISS, Hubble, Chang’e)
- Other planets and missions to visit/photograph (such as Mars, Neptune, moons of Jupiter)
- The Sun and nearby stars
- Health and science of living in space

Execution: Senior students can use available information from existing space platforms to explore the universe and carry out scientific research based on their own hypotheses. By mentoring junior students they achieve learn-by-teaching objectives while inspiring younger students to go beyond the curriculum. Younger students can be introduced to the same concepts on an age-appropriate basis and should be encouraged to engage their parents in learning about space and space exploration together.

Mentor Options: Local space agency or universities

Supplemental Materials:

- Link space lessons to current events (such as Mars, Moon, Near Earth Objects)
- Educational games from NASA, ESA, CSA, and other sources
- Planetarium visit
- Use of telescopes for night-time viewing

Follow-up Topics:

- Artwork to express understanding of the concepts
- Proposals for future research based on student questions

4.4.2 The Space Cycle Game

Leveraging existing platforms used for electronic gaming is a key concept in future education initiatives. Making the learning process fun and interactive changes the dynamic flow of information from sit-and-listen to play-and-learn. People of all ages are able to access and play online games on their own schedule, without relying on a typical classroom setting.

The “Space-Cycle” is a game concept that teaches players about the life cycle of space-based assets. The vast majority of people around the world are familiar with satellites and the process
of launching them into space, however very few people are aware of the looming threat posed by an ever-increasing amount of space debris in Earth’s orbit.

The Space-Cycle game would run on existing mobile devices such as smart-phones and tablets. The game is intended to make the learning process fun by making the student play-and-teach rather than sit-and-listen. Such a game could be accessed by people of all ages and grade levels, on their own schedules, without relying on classroom infrastructure. The figures in this section are concept art for the Space-Cycle game.

This game starts the user at a remote terminal access to Anomaly-Corp’s computer network. The player is given a mission, such as operating a communication satellite, with objectives and limitations that can be changed with each game. Figure 4-5 shows the welcome screen and an example of the mission instructions.

![Space-Cycle Game Concept Art - Welcome Page and Start Page](image)

**Figure 4-5:** Space-Cycle Game Concept Art - Welcome Page and Start Page

The process of assembling a satellite to meet objectives introduces the user to the concept of systems engineering in a highly simplified manner. The user then must piece together a rocket capable of lifting that satellite into orbit, covering topics such as thrust, gravity, payload capacity, and cost. Figure 4-6 shows the satellite and rocket builder pages.
Before launch is possible they must also determine the orbital mechanics of the launch by selecting a location and launch angle. This introduces the components orbital dynamics and teaches the user about launch and orbit parameters. Figure 4-7 shows the error interface and the mission accomplished page.
Once the satellite reaches orbit, the player must use the limited fuel supply to adjust orbit parameters to avoid incoming space debris. If the satellite collides with too many pieces of space debris it will explode and further contaminate the orbit. Figure 4-8 shows the on-orbit operation activity.
Figure 4-8: Space-Cycle Game Concept Art - On-orbit satellite operation

Before another launch is possible a space debris removal plan must be designed and implemented. The user pilots a space debris removal craft and uses various methods to capture and mitigate the dangers posed by space debris. These activities teach the user about a satellite’s life cycle, and how to address the bits of space debris that are left behind. Figure 4-9 shows the space debris removal activity.
The mock-ups of game screens were formatted to match the screen of a standard tablet device. This game concept could also be adapted for display in a web browser to reach a wider audience. It could also incorporate online scoreboards or multi-player options to drastically increase the depth and difficulty-level of the material covered, depending on the audience and experience level. A “Discover” link can be used to lead the user to more information relating to the game concept is provided on the main page. Students/teachers can click to find links to other places on the Internet that cover each of the concepts in more detail for supplemental lessons.

The Space Cycle game satisfies the following recommendations from Table 4-1:

- Includes developing countries
- Available and designed for all cultures and genders
- High accessibility with low costs
- Provides accessible resources for teachers
- Improve students’ perception of STEM being too difficult
- Can be used as an introduction of why it is interesting and important
- Incorporates art as a design process
- Incorporates art as an experience
4.4.3 World Space Week Coordination

There is an extensive collection of space-related materials available via the Internet, but their usage, both in and out of the classroom remains low. This suggests that better knowledge of what materials are available could significantly increase the usage of space-related education. An international event could be used as a publicity device to increase the public awareness and dissemination of these teaching materials.

On December 6, 1999, the United Nations General Assembly officially declared October 4 to 10 to be “World Space Week to celebrate each year at the international level, the contributions of space science and technology to the betterment of the human condition.” (UN General Assembly resolution, 6 December 1999)

The World Space Week event could be used as a springboard to encourage teachers to bring space into the classroom. Ideally, the United Nations Office for Outer Space Affairs (UNOOSA) could coordinate with governmental education bodies in countries throughout the world to encourage them to make use of existing space-related educational materials. With governmental encouragement, it should be fairly easy to integrate these existing educational products within existing curriculums worldwide.

Education is not restricted to the classroom, and young children are greatly influenced by what they watch on television. Sesame Street is a well-known and very popular educational program viewed in over 120 countries around the world. Sesame Street has a history of working with NASA; the character Elmo visited KSC for the final launch of the American Space Shuttle (Figure 4-11), and has made other appearances with NASA personnel. This existing partnership could be extended to show space-related programming during World Space Week and provide a direct method of encouraging an early interest in space content in children. If the space-related programming were integrated, or carried by the international versions of Sesame Street, this outreach could reach a significant audience worldwide.
Other networks such as the Disney Channel and Nickelodeon, which have a large following of children spanning a wide range of ages around the world, could provide similar outreach to a large group of older children and teenagers. Ideally, the networks could emphasize the topic of space in their programming or show a special episode of some of their original shows during World Space Week.

The International Youth Rocketry Challenge is a fairly new effort sponsored by the Aerospace Industries Association. It began as a spin-off from the Student Launch Initiative, a secondary school rocketry competition held annually in Alabama, USA, since 2003. Over the past several years the competition has grown to include three countries: the United States, the United Kingdom, and France. With the right communication, this competition has the opportunity to grow to include many more countries, and provide the kind of inspiration necessary to promote interest in studying STEM fields. A coordinated rocketry competition during World Space Week could provide excellent STEM outreach at a variety of age levels.

Ideally, the World Space Week organization, with sufficient manpower and collaborating with UNOOSA, could coordinate these efforts with the organizations described above, and likely many more. Knowing that they were one of several networks and organizations participating in this effort would provide further encouragement to the individual networks and organizations to participate.

Coordination of communication efforts through multiple channels using an international event such as World Space Week satisfies the following recommendations from Table 4-1:

- Available and designed for all cultures and genders
- High accessibility with low costs
- Improve students’ perception of STEM being too difficult
- Can be used as an introduction of why it is interesting and important
- Incorporates art as an experience
4.4.4 On-Orbit Student Competitions

The Center for the Advancement of Science in Space (CASIS) was designated in 2011 as the sole manager of ISS US National Laboratory (Destiny). They are charged with facilitating access to the advanced research facilities in Destiny. CASIS has a strong educational arm, and works closely with NASA and many research organizations and students throughout the United States to motivate them to pursue STEM fields. They promote the use of ISS facilities for the study of plant science and microbiology, and human biology and medicine. Their STEM education office is working closely with the research office to extend educational opportunities, ensuring that all research proposals sent to universities and other research organizations include an educational component.

CASIS is hoping to work with technology companies, including video game companies and the entertainment industry, to find ways to be able to interact in real time with the hardware on the ISS. These companies use high definition, 3-D graphics, and virtual reality technology to engage players in the worlds they create. The goal would be to use this technology to capture the feeling of being on-orbit inside the Destiny laboratory. These technologies would ideally be leveraged on any future space stations to enhance this experience.

Similar efforts in Europe are organized by the staff of the ESA education office. They select the projects that will be conducted on board the Columbus Laboratory based on budgetary constraints and the schedule imposed by the various experiments on orbit.

In Japan, the JAXA Space Education Center coordinates the use of resources aboard the Kibo module. They coordinate educational events and provide student opportunities to promote interest in space, science, and human space development through ISS utilization.

For a future space station, the idea of an organization like CASIS can be extended to create a single organization responsible for the resources within a set of international laboratories. This would allow for a more equitable distribution of resources, as well as allow for students the world over, not just the US, Europe, and Japan, to participate directly in on-orbit space science research.

Student competitions motivate students to work hard and often cause them to achieve more than they thought they could. Despite the cultural difference in student motivations, student experiment competitions on board a space station can foster scientific discoveries and inspire students to pursue STEM fields.

The current ISS has a wide variety of scientific equipment in the laboratory modules that could be used in student competitions. Looking toward future space stations, this concept could be built into the initial design to provide more scientific equipment dedicated to student use and minimizing the impact on the crew. Many different types of student competitions could be run using these resources; two illustrative examples of potential competitions are described below. The major impediment to these types of experiments is their current impact on the crew’s mission timeline. Both of these examples have to potential to incorporate the virtual reality and other new technologies described above to reduce their requirement on crew time. The only requirement to participate in these experiments is a computer and an Internet connection.
Promoting new space station-based student competitions satisfies the following recommendations from Table 4-1:

- Includes developing countries
- Available and designed for all cultures and genders
- High accessibility with low costs
- Supports guided, hands-on learning
- Improve students’ perception of STEM being too difficult
- Can be used as an introduction of why it is interesting and important
- Has a formal process to assess student learning and attitude
- Provides a system for evaluation and feedback allowing improvement

4.4.4.1 Grow the Largest Sunflower in Space

Students would be provided supplies to grow a sunflower, most likely using hydroponics on a space station. The goal would be to grow the largest flower in a particular amount of time. Through this, students would learn about the plant life cycle, robotics, and space station operations. They would also have to study the differences between plant growth behaviors in a 1-g environment on earth and a microgravity environment in orbit. While preparing for and conducting these experiments, the students would learn about gravitropism (perception of gravity), responses to environmental stimuli (such as light, gravity, and magnetism), and the effect of irregular lighting conditions on circadian rhythms (Figure 4-12).

![Microgravity Seedling from the Cell Biology Experiment Facility](https://example.com/image.jpg)

**Figure 4-12:** Microgravity Seedling from the Cell Biology Experiment Facility Life Cycles of Higher Plants under Microgravity Conditions (SpaceSeed) [online]

This competition has applications for the future of international space efforts, as plant growth will most likely be an integral part of long-duration space missions. Students will gain a greater understanding of how plants grow in space and will be better positioned for careers in this developing field.
4.4.4.2 Protein Crystal Growth Competition

Students would investigate the mechanisms of proteins growth, and attempt to grow a protein of a given shape and size within a limited amount of time. The ISS currently has a Commercial Protein Crystal Growth payload that is used "...to grow high-quality crystals of selected proteins so that their molecular structures can be studied." (spaceref.com, 2012) It has been found that in microgravity conditions, protein crystals grow in a more regular matrix structure (Figure 4-13). These more ordered crystals have significant potential in the pharmaceutical and agricultural industries. Involving students in this experiment would encourage them to learn about the biological mechanisms involved in proteins, and their potential medicinal applications.

Figure 4-13: Example from Protein Crystal Grown in Microgravity
Commercial Protein Crystal Growth - High Density (CPCG-H) [online]

4.4.5 Textbook Updates

There is an opportunity available for space to be included in the current STEM textbooks by modifying examples in today’s curriculum to use space content. This is a simple but efficient way to introduce space to the curriculum. Space will be one of the major activity sectors of tomorrow so it should be reflected in textbooks. Students need to be prepared for jobs that might not yet exist; therefore textbooks need to be oriented toward the future of STEM, and not the past. Space can further be used to change the image of STEM, making it more attractive and inspiring. For example, it is common to explain that

\[ \text{Distance} = \text{Speed} \times \text{Time} \]

by using an example involving a car traveling at a certain speed for certain distance and asking the student to work out the time for the trip. Space-related examples, such as the speed of a signal traveling to a satellite rather than the speed of a car, could be used to add variety and inspiration to these types of examples. These types of substitutions could be used for a variety of topics as shown in Table 4-2.
Table 4-2: New Textbook Examples

<table>
<thead>
<tr>
<th>Topic Examples</th>
<th>Possible Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geometry and Trigonometry</td>
<td>The rotation of a satellite. The angle of approach for a landing spaceship. Calculating the area of a solar cell.</td>
</tr>
<tr>
<td>Probability</td>
<td>Calculate the number of possible meals given the limited space foods. Calculate the reliability of a certain combination of spacecraft systems.</td>
</tr>
<tr>
<td>Calculus</td>
<td>Calculating the orbits and motion of a satellite. Using Integration to calculate the volume of space station structures. Using differentiation to calculate the acceleration of a rocket.</td>
</tr>
<tr>
<td>Mass and Volume</td>
<td>Estimating the volume of a fuel tank on a rocket. Calculating the mass of celestial bodies.</td>
</tr>
</tbody>
</table>

These types of examples could be quickly and cheaply integrated into demonstrations and problem sets in the STEM education system without causing significant changes to the current STEM curriculum.

Updating textbooks to include space-related applications as examples satisfies the following recommendations from Table 4-1:

- Includes undeveloped countries and developing countries
- Available and designed for all cultures and genders
- High accessibility with low costs
- Supports guided, hands-on learning
- Provides accessible resources for teachers
- Improve students’ perception of STEM being too difficult
- Can be used as an introduction of why it is interesting and important
- Has a defined set of criteria that can used to compare to other existing solutions
- Provides a system for evaluation and feedback allowing improvement
- Incorporates art as a design process and as an experience

4.4.6 Khan Academy Extension

Khan Academy is a free website containing hundreds of educational videos dedicated to teaching numerous topics such as science, technology, engineering, and mathematics.

The Khan Academy approach fulfills many of the recommendations defined in Chapter 2. Khan Academy is easily accessible in many countries and requires only a computer, an Internet connection and basic English proficiency. Khan Academy provides automated tools to allow teachers to monitor the progress of students. The Khan Academy approach provides teachers with more time for guided inquiry-based learning, by allowing skills learning to occur outside the traditional classroom setting.

Incorporating space-related content into the Khan Academy lectures could increase student engagement, provide exciting examples for the students, and introduce students to the field of space studies. Space also provides beautiful imagery of the universe that is well-suited to the
video format of Khan Academy. New space-related content could be added to the Khan Academy easily and at minimal cost.

Extending the Khan Academy website to promote space-related materials satisfies the following recommendations from Table 4-1:

- Includes developing countries
- Available and designed for all cultures and genders
- High accessibility with low costs
- Supports guided, hands-on learning
- Provides accessible resources for teachers
- Improve students’ perception of STEM being too difficult
- Can be used as an introduction of why it is interesting and important
- Has a formal process to assess student learning and attitude
- Has a defined set of criteria that can used to compare to other existing solutions
- Provides a system for evaluation and feedback allowing improvement
- Incorporates art as a design process and as an experience

4.4.7 **Video Outreach**

Social media, YouTube, and other online content are playing an increasingly important role in shaping students’ perceptions. The educational video “The Symphony of Science, The Quantum World,” has obtained over 2.3 million views on YouTube in less than a year (Boswell, 2011) providing a huge potential audience to educate and engage in STEM fields. This video was not specifically made for the classroom; however, its creator John Boswell has received very positive feedback from teachers that have used it to teach their students (Boswell, 2012).

Short videos of this type are not a way to delve deeply into subject matter or to teach fundamental concepts, but they work well to motivate students and overcome their misconceptions about STEM subjects. A video titled “The Universe is Just Awesome” has been created to complement this report and show students around the world a brief glance of a wide variety of space concepts. It is based on the widely successful “The World is Just Awesome” advertising campaign from 2008 that has amassed almost seven million views on YouTube (Discovery Networks, 2012).

“The Universe is Just Awesome” shows short clips of different people each singing a single line of a song about how much they love space. Each line of the song starts with “I love the …” followed by the name of the thing that the person loves. The simplicity of the song’s lyrics, shown in English in Figure 4-14, and its catchy chorus should appeal to a wide audience. The song lyrics are sung in a variety of different languages to emphasize the international scope of space activity. Subtitles at the bottom of the screen provide a translation of the lyrics into the language of local student bodies around the world.
I love the planet
I love the solar Flares
I love the rockets
I love the astronauts

I love the Universe
And all its energy
Boom-De-Yah-Dah, Boom-De-Yah-Dah
Boom-De-Yah-Dah, Boom-De-Yah-Dah

I love our satellites
I love the nebula
I love the big bang
I love microgravity

I love the universe
And all its craziness
Boom-de-yah-dah, boom-de-yah-dah.
Boom-de-yah-dah, boom-de-yah-dah.

I love white dwarfs
I love our atmosphere
I love the comets
I love the galaxies

I love the universe
It's such a brilliant space
Boom-De-Yah-Dah, Boom-De-Yah-Dah
Boom-De-Yah-Dah, Boom-De-Yah-Dah (fade out.....)

**Figure 4-14:** I Love the Universe – English

This video is designed to be a motivational tool in the classroom and to be disseminated using social media like Facebook and YouTube. This video will help motivate students and show them the awesomeness of the universe in a way that they can appreciate. It will serve as a tool for teachers to use inside the classroom to introduce their STEM students to space. By creating “The Universe is Just Awesome,” it shows that producing short, high quality educational clips for the classroom on a near-zero budget is possible and worthwhile for producers of educational material.
Creating and distributing a motivational video such as “The Universe is Just Awesome” satisfies the following recommendations from Table 4-1:

- Includes undeveloped countries and developing countries
- Available and designed for all cultures and genders
- High accessibility with low costs
- Provides accessible resources for teachers
- Improve students’ perception of STEM being too difficult
- Can be used as an introduction of why it is interesting and important
- Incorporates art as a design process and as an experience

4.5 Bringing Space to Student Evaluations

Space-related STEM content generally has two major objectives: to help students to understand learning outcomes within the existing curriculum (Space to Educate), and to motivate and inspire students to engage with their studies (Space to Inspire). Although these objectives are interrelated, they are distinct and need to be evaluated separately.

Appendix B shows how standardized student assessment is a concept that has evolved considerably in the last century. Evaluation techniques appear to be shifting from module level testing of discrete concepts toward interdisciplinary testing that requires students to synthesize, apply, and think about the material. Because space-related disciplines tend to draw simultaneously from multiple education disciplines, they are well-suited to this type of synthesis evaluation.

As previously described, PISA is an internationally recognized standard to assess student performance at a country level and determine the factors that influence student success. The PISA contains questions designed to assess both learning outcomes (cognitive items) and their attitude toward the material (attitudinal items) (OECD, 2006). The PISA is designed to evaluate groups of students statistically, and the scaling and normalizing applied to the results make it unsuited for evaluating individual students. This report finds that the PISA approach could form an excellent basis to evaluate student learning outcomes from space-related STEM content. It is recommended to use space-related PISA-style questions to prompt deeper student understanding and introduce new academic disciplines.
4.5.1 Evaluating Student Learning

Figure 4-15 shows an example PISA question evaluating student understanding of the concept of momentum (OECD, 2007).

**Question 3 : Stimulus**

**BUSES**

A bus is driving along a straight stretch of road. The bus driver, named Ray, has a cup of water resting on the dashboard:

```
1 2
   .
```

driving direction

Suddenly Ray has to slam on the brakes.

**Figure 4-15: PISA Test Question Assessing Student Understanding of Momentum (OECD, 2007)**

The student is then asked to select from three possible choices:

1. The water will stay horizontal.
2. The water will spill over side 1.
3. The water will spill over side 2.

This question places the scientific concept of momentum in a familiar, everyday context that most students can understand and asks them to apply and extrapolate. Space-related follow-up questions could prompt the students to contemplate the subject and to introduce new disciplines. The following three questions assume the students have been introduced to microgravity using an example such as the International Space Station.

1. A spaceship is orbiting the Earth providing a microgravity (“weightless”) environment. The driver, named Rachelle, wants to have a drink of water. What problems might Rachelle experience if she tried to store the water in a normal cup?
2. Draw and describe a new kind of cup to help Rachelle have a drink of water in her spaceship microgravity environment.
3. Suddenly, Rachelle moves her spaceship to avoid an asteroid. Describe what will happen to the water in the new cup.
Question 1 prompts the students to distinguish between mass, weight, and momentum. Question 2 introduces the student to an engineering style design problem. Question 3 synthesizes the science and engineering questions and prompts the student to evaluate and reconsider their previous work. These types of space-related extension questions not only test the student’s understanding of the core scientific concept of momentum, they also assess the student’s ability to apply the knowledge to a less familiar situation and apply this knowledge in a design process.

### 4.5.2 Evaluating Student Engagement and Interest

The 2006 PISA study attempted to assess student engagement and interest in science using periodic attitudinal questions that do not influence the student scores. For example, a series of questions on the chemistry of acid rain are followed by the attitudinal question shown in Figure 4-16. It was emphasized to students that this question did not have a “correct answer” and would not affect their grade on the test.

**Figure 4-16: PISA Question Evaluating Student Engagement and Interest (OECD, 2006)**

This style of question could assess a student’s interest in STEM and in the subject matter. A space-related question like, “How similar are the chemical processes that might endanger astronauts on the International Space Station?” could assess if a student sees a relationship between space activities and life on Earth. It could also measure whether a student finds the references to space more or less engaging than the conventional material.
4.6 Discussion

Space can help promote STEM education worldwide regardless of whether a country has a developed space program. National space agencies around the world provide a variety of space-related education materials that are readily available from their websites. Nevertheless, the uptake of these materials appears to be low, which reduces their effectiveness in stimulating STEM education. This suggests that one of the biggest issues of these programs is their lack of visibility and outreach. Space activities are not part of the curriculum in all countries, are often not familiar to teachers, and are often not proposed to the entire community. Space and its applications should be promoted to the global public to make them more aware of its relevance to their lives and their society.

Introducing space in the classroom will serve to ignite curiosity and imagination within students and help them stay engaged and encouraged to pursue STEM studies. The products and solutions presented in this chapter are easy and simple additions to the existing school curriculum and reach children of all ages. Existing products such as textbooks or Khan Academy material can be quickly and cheaply updated with space-related content. Space workshops are easy to implement and use in the classroom. New products such as the Space Cycle Game or the on-orbit student competitions take longer to develop, but provide meaningful student engagement. Each of these solutions was designed to address the recommendations presented in Chapters 2 and 3, and demonstrate that space-related content can enhance STEM education both inside and outside the classroom (reference Appendix F). Space can also be further used for student evaluation through its interdisciplinary approach. These new and improved space-related materials can add a much needed dynamism to the STEM education of tomorrow.
5 RECOMMENDATIONS

The principal recommendation of this report is that space-related educational content should be used to inspire students to engage with their academic studies and motivate them to pursue careers in STEM. This report recommends the following seven examples of how space can be integrated into STEM education:

- Workshops
- Space Cycle Game
- Utilizing World Space Week
- On-Orbit Student Competitions
- Textbooks Updates
- Khan Academy Extension
- Video Outreach

This report also recommends that, to ensure that new space-related educational content is effective and reaches the widest possible audience, it should:

- Be accessible to all cultures and genders
- Have a low cost to implement
- Challenge the perception that STEM is too hard
- Be interesting and relevant to students
- Be relevant to developed, developing and least developed countries
- Support guided hands-on learning
- Be easily accessible and reachable by teachers and other educators
- Provide a system for evaluation and feedback to improve the teaching material
- Incorporate art as a design process
- Incorporate art as an experience
- Have a formal process to assess student learning and attitude toward the material
- Have a defined set of criteria to compare it with existing teaching material

By following these recommendations educators can use space to change how students view science, technology, engineering, and mathematics fields and encourage them to engage with the academic studies and pursue related careers.
6 CONCLUSION

This report presents the research and proposals on how space can be used as a medium and driver for STEM education. Many developed and developing countries are experiencing declines in STEM education. Many least developed countries view STEM as important but are still struggling to provide rudimentary education. Many countries are actively working to improve their STEM education system and change the common perception of STEM as elitist, hard, and boring.

The first step to improving STEM education is identifying its context in various societies and education systems. International and multidisciplinary research has identified social and methodological challenges to STEM education. A major problem is that most 21st century educational systems are essentially the same as those developed for the industrial revolution one hundred years ago. Old teaching methods are no longer appropriate for modern students who were born into a technology driven world. The inertia of the classical education system and its values can be an impediment to changing STEM stereotypes and teaching methods.

Art can be used to connect space and STEM in a more attractive way and improve and extend the thinking ability of STEM students. The process and experience of art are important for design, creative thinking, and bringing humanity to STEM as well as STEM to humanity. This report encourages the use of space to promote STEM education in order to increase the motivation of school-aged children and extend the current STEM audience. New global and affordable teaching and evaluation methods were suggested that utilize society’s technological progress and current youth needs. Recommendations to evaluate and improve space-related STEM products have been developed and examples are provided.

Imagination, innovation, inspiration to exploration, and the potential to answer the most fundamental questions of humanity attract many people of all ages to space. This is why ISU strives to establish an educational module on-board a space station by the year 2040 (ISU Academic Council, 2011). Space provides a new perspective and collaborative environment that can help challenge stereotypes, and lead to national, cultural, and gender equality. Using space to promote STEM education helps develop open-minded and creative future leaders.

This report sought to answer the question “What can space contribute to global STEM education?” It has shown that the inherent power of space to provide wide appeal and inspire and motivate students can be leveraged to improve STEM education. This will encourage students to engage with their studies and pursue higher education in STEM fields. Space-related content can provide a Giant Leap for Education!
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APPENDIX A: THE GLOBAL STEM SITUATION

In support of section 2.1, the specific situations in several countries were analyzed. They are presented here.

Developed Countries:

Japan:

Japan is witnessing a decrease in its student enrollment in STEM subjects. Science and mathematics are especially representative examples, because it is not possible to take advantage of natural resources in Japan without science and technology. As stated on the Ministry of Education, Culture, Sports, Science, and Technology (MEXT, 2012) website:

“MEXT is therefore working on comprehensive human resources development measures spanning everyone from children to leading researchers and engineers. MEXT is doing this by developing the talents of young children, broadening the horizons of children who like science, fostering environments where diverse people including young, female, and foreign researchers can exercise their abilities, and promoting a professional engineer system.”

As part of the Japanese education curriculum, MEXT and the Japan Science and Technology Agency (JST) have several programs. One of these is the “Super Science High School” project that started in 2002, in which MEXT selects some high schools and implements special curricula to recognize and develop promising students. This program involves:

- presenting and listening to lectures and lessons in English to overcome the language barrier (Japanese-English);
- developing teaching materials to learn effectively; and
- Involving students in international competitions.

MEXT provides a five year funding program to high schools to use for cooperation with universities and research institutions. The purpose of this program is to promote upper secondary education to foster promising human resources in science and technology. As part of this program, children must pass exams to qualify for enrollment in one of these selected schools.

JST organizes the “International Science Technology Contest,” which includes many events related to STEM education. Some examples include the International Mathematics Olympiad (IMO) and the International Chemistry Olympiad. Through participation in these events, students’ interest in STEM fields is increased. Participants from Japan who participated in IMO in 2011 won two gold medals, two silver medals, and two bronze medals (JST, 2012).
France:

In France, the problem is not so much that primary and secondary education is not efficient in producing good STEM studies, rather, the best French secondary students, who are knowledgeable in STEM disciplines prefer to study business subjects (Lemaire, 2004). The result is that engineering schools, which historically produced some of the best students, now tend to produce lesser quality students, while the more qualified students are inclined toward finance, business, and management. France is, however, making efforts to promote science and engineering professions through interactive science museums like the French Cité des Sciences et de l’Industrie, located in Paris.

Israel:

As in many developed countries, Israel observed a decreasing number of recipients of first degrees from institutions of higher education from 1970 through 2009.

![Graph showing declining Israeli degrees in sciences, mathematics, engineering, and architecture](image)

**Figure A-1:** Declining Israeli Degrees in Sciences, Mathematics, Engineering, and Architecture (Data from the Central Bureau of Statistics in Israel, 2010)
**Developing Countries:**

**Brazil:**

When compared to other countries with similar development levels, Brazil is lacking in science and mathematics education. The few scientific and technological centers are not accessible to everyone. Also, the priority for science education was lowered after 1994 due to changes in government policy (Waiselfisz, 2009). PISA results in 2009 show that Brazil has been gradually getting better results in performance but only enough to reach what is considered a baseline level of proficiency (OECD, 2010).

**India:**

In India, STEM disciplines are pursued by students because they feel like they are contributing to the advancement of their country’s technological development (Spacemart, 2012). STEM fields, however, are still limited to wealthier students.

Performance in science and technology in India is “...singularly uneven...” and “...the best in the country is often about as good as anywhere in the world, but the worst is poor” (Narasimha, 2008). India’s 1968 National Educational Policy highlights equitable expansion of educational facilities, and stresses the need to focus on education for girls (Shukla, 2005).

The India Science Report (Shukla, 2005) gives the following major findings about the status of science and engineering education in India:

1. In 2004, about 25% of students qualified for graduate studies and above had a background in science education. There are 39.2 million graduates in all (22.3% of whom have science education backgrounds), 9.3 million postgraduates (19.4% of whom have science education backgrounds), and 0.3 million doctorates (33% of whom have science education backgrounds).
2. Annual enrollment at the post-graduate level has risen from 6.6 million students in 1995–96 to 9.84 million in 2004, including 0.34 million in doctorate courses, and the proportion of those studying science has risen from 28.8% in 1995–96 to 34.6% in 2004.
3. The proportion of those studying engineering has almost doubled, from 6.0% of the population studying at the post-graduate level in 1995–96 to 11.2% in 2003–04. Indeed, engineering education shows the highest growth, from 8.2% per annum in 1995–2000 to 21.9% in 2000–04.
China:
In China, the government advocates educating its children starting at an earlier age and continuing for more years than in other countries, with greater emphasis on mathematics and science. Chinese students understand that if they obtain those skills, they will be able to find a good job (TMI, 2012). These highly qualified mathematics and science students support the rapid growth of China’s economic and space industries. The Chinese government, understanding that innovation and creativity are needed to sustain growth, is looking closely at the education systems of developed countries for ideas. They are looking especially closely at developing STEM education for the cultivation of interdisciplinary and innovative talents in the 21st Century (Wen, 2012).

On 5 March 2012, Chinese Premier Wen Jiabao gave a speech outlining the countries strategy for science, technology, and education. This speech included commitments such as:

- “We will insist on giving priority to the development of Education. The central government has prepared its budget to meet the requirement that government spending on education accounts for 4 percent of the GDP."
- “We will strengthen preschool education, continuing education, and special education to aid in the building of a modernized education system.”
- “We will enhance the work on human resource, and thoroughly reform the human resource system in order to train up a group of innovative youngsters, and where there is a shortage of talent, to bring a higher level of intelligence. Finally we will implement the training, assigning, evaluation, and motivation system in human resources.”
  (Xinhua, 2012)

Romania:
Similar to many countries in Europe and the Americas, Romania presents a decreasing trend regarding the interest of students in STEM education. There is also a big gap in results between the highest achieving and the least achieving students. Romanian mathematics students rank in the top ten in the world according to international mathematics competitions.
APPENDIX B: HISTORY OF EVALUATION

In 1972, the quantitative marking system was introduced by William Farish to assess students’ performance. This system supports the objective ranking of students, and the establishment of aggregate scores for students. Since that time, the educational evaluation system has evolved (Hogan, 2007).

In 1864, the Scale Book concept was put forth by Reverend George Fisher of Greenwich Hospital School in England. This fixed standards book of estimation contained numbers, which graded the degree of proficiency for the subjects to be examined. As an example, to determine the best writings submitted by a group of students, they are ranked using the Scale Book concept. Ayers (1918) stated “Fisher and Price were forbearers to the real beginning of the scientific measurement of educational products.”

In 1916, Thorndike and a group of his students developed standardized tests in reading, arithmetic, and drawing (Thorndike, 1918). Thorndike established several concepts on educational evaluation, stating:

“. . .that education involves the measurement of complex endeavors with endless dimensions from which we must abstract concrete representations for measurement; that scale matters; that the validity of measures must be confirmed with empirical evidence; that reliability and accuracy are essential and require multiple measures; that the use of single tasks or items is not sufficient; and that assuring fairness is challenging.”

These concepts are widely implemented today for educational evaluation.

The 1930’s began an eight year study to investigate the application of progressive education and the effectiveness on curriculum at high schools. The new objectives-based framework for testing was introduced by Dr. Ralph Tyler at the University of Chicago. The main essence of this framework, as stated by Tyler (1949) is the “. . .assessment in curriculum development and improvement.” Tyler laid the foundation for the education evaluation models, and put forth four basic principles of curriculum and instruction:

1. define appropriate objectives;
2. establish useful learning experiences;
3. organize learning experiences to have maximum impact;
4. evaluate achievement of the objectives, and revising as necessary those aspects of learning that were not effective (Tyler 1949)
From the 1950's through the 1970's, the principal focus of the theory and application in educational testing was measurement-driven instruction. Based on the principals, models were widely used for evaluation in elementary schools throughout North America. The Mastery learning model divides the curriculum material into small units that needed to be mastered in sequential order, with mastery tests constructed for each of these units. The results of the end-of-unit tests were used to determine which students would continue to the next learning unit and which students needed more time to study the same unit again. The students who needed more time were taught again using different methods of instruction, which included peer tutoring (Haertel and Herman, 2005).

The "What Is Happening in this Class?" questionnaire is a method of evaluating the classroom learning environment, and has been used extensively in research. This questionnaire was the result of many years of research, which allowed educators to develop a more in-depth understanding of how students learn and the complexities of factors that can affect the teaching and learning process. For these reasons, it may be one of the methods of evaluation suitable for today's classroom environment (Pickett et al., 2010).
APPENDIX C: EVALUATION METHODS TABLE

Traditional evaluation consists mainly of exams and written tests. Table C-1 summarizes the main differences between traditional and alternative evaluation (Armstrong, 1996). The alternative evaluation method is encouraged because it is the most comprehensive method of evaluation. Evaluating only by exam grades does not present equal opportunities to all students to show their capabilities.

Table C-1: Comparison of Traditional and Alternative Methods of Student Evaluation

<table>
<thead>
<tr>
<th>Points of comparison</th>
<th>Traditional</th>
<th>Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significance of educational/learning achievements</td>
<td>Assumes that there is a universal meaning to achievements - meaning a grade in a certain test is of the same significance to each and every student</td>
<td>Assumes that in a multi-cultural society, differences and contrasts in perspectives are inevitable and consensus is not desirable</td>
</tr>
<tr>
<td>Teaching and evaluation</td>
<td>Are disconnected</td>
<td>Are interrelated</td>
</tr>
<tr>
<td>Assessed skills</td>
<td>Cognitive only. Mostly logic and linguistic</td>
<td>Cognitive, as well as social and creative</td>
</tr>
<tr>
<td>Tools</td>
<td>Exams, written tests</td>
<td>Compiling a portfolio, creating a game, writing an essay, presenting to class, conducting an experiment</td>
</tr>
<tr>
<td>Type of assignments</td>
<td>Synthetic. Not real-world questions</td>
<td>Authentic, relevant to students' everyday life</td>
</tr>
<tr>
<td>What is assessed</td>
<td>Only final products</td>
<td>Final products, the process, reflection skills, initiative, creativity</td>
</tr>
<tr>
<td>Who is the evaluator (the rater)</td>
<td>Teacher and/or experts</td>
<td>Teachers and students (self-evaluation), colleagues, parents. Evaluation by dialogue.</td>
</tr>
<tr>
<td>Evaluation criteria</td>
<td>Predetermined, often not fully explained to the students</td>
<td>Created with the student, a dialogue with the teacher</td>
</tr>
<tr>
<td>Who is responsible for evaluation?</td>
<td>The teacher</td>
<td>Teacher and student share responsibility</td>
</tr>
<tr>
<td>Measurement and report</td>
<td>Numeric grade</td>
<td>Comprehensive performance profile</td>
</tr>
<tr>
<td>Evaluation goal, objective</td>
<td>External review of the system</td>
<td>Sets standards and defines goals to teaching</td>
</tr>
</tbody>
</table>
APPENDIX D: EVALUATION METHODS

National Research Council (NRC, 2004) presents a more scientific approach to curriculum evaluation, and describes four major evaluation methodologies:

1. Content analysis: Rely on experts to examine the content of curriculum materials, and judge the correctness, depth, and logical arrangement of topics.
2. Comparative studies: Identify important elements to compare different curriculum, preferably over a considerable time period.
3. Case studies: Analyze a particular curriculum to study how program theories and components are applied in actual life situations. These analyses typically portray and discuss different factors that affect how the program might be implemented in class.
4. Synthesis studies: Review selected case studies and content analyses of a particular curriculum.

The paper differentiates between two dimensions of teaching material evaluation:

1. Scientific validity: Individual studies should follow a well-defined methodology out of the four discussed above, and tackle the elements and issues presented in their frameworks.
2. Judging curricular effectiveness: Judgment should be based upon an integrated work of several studies that link social values, empirical evidence, and theoretical rationales. For instance, content analysis is important because it provides good indications for the quality of the material, goals, and required student achievement. But content analysis cannot predict how well they will be implemented in the classroom.

Educational evaluation and assessment techniques have evolved over time. Numerous international studies have been conducted to understand differences in effectiveness of mathematics and science education in various countries. PISA is used internationally to assess teaching environments. It is important to consider the differences in educational curriculum and evaluation methods across different countries when evaluating students’ performance and the curriculum. Students and teachers should be assessed using a comprehensive mixture of direct and indirect assessment methods. In addition, the global trend for education evaluation is based on three main reform strategies:

- “standardization of education;
- increased focus on the literacy and numeracy; and
- consequential accountability systems.” (Sahlberg, 2007).

New evaluation methods should include comprehensive evaluation and feedback systems in it, and should have formal processes so that school performances can be evaluated.
APPENDIX E: TARGET AUDIENCES

Figure E-1 shows the major stakeholders of STEM education. Each of these stakeholders is a potential target audience for new space-related content developed in section 4.4.

Figure E-1: Possible Target Audiences for New Space-Related STEM Content
Different mediums are suited to different target audiences. Table E-1 shows the best medium for each of the new space-related STEM products to reach their target audiences. The mediums are: online webpages, annual conferences, published papers, space agencies, and ISU alumni.

Table E-1: Target audiences for new STEM activities

<table>
<thead>
<tr>
<th>Medium</th>
<th>Audience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workshops</td>
<td></td>
</tr>
<tr>
<td>Annual Conferences</td>
<td>Teachers, private schools</td>
</tr>
<tr>
<td>Published Papers</td>
<td>Teachers, private schools, nongovernmental organizations</td>
</tr>
<tr>
<td>Space Agencies</td>
<td>Ministries of education, nongovernmental organizations</td>
</tr>
<tr>
<td>Space Cycle Game</td>
<td></td>
</tr>
<tr>
<td>Annual Conferences</td>
<td>Teachers, private schools</td>
</tr>
<tr>
<td>ISU alumni</td>
<td>Teachers, ministries of education, nongovernmental organizations</td>
</tr>
<tr>
<td>Online AppStone</td>
<td>Teachers, students, parents</td>
</tr>
<tr>
<td>Space Agencies</td>
<td>Teachers, ministries of education</td>
</tr>
<tr>
<td>On Orbit Competitions</td>
<td></td>
</tr>
<tr>
<td>Annual Conferences</td>
<td>Teachers, private schools</td>
</tr>
<tr>
<td>Published Papers</td>
<td>Teachers, private schools, nongovernmental organizations</td>
</tr>
<tr>
<td>Space Agencies</td>
<td>Teachers, ministries of education</td>
</tr>
<tr>
<td>World Space Week</td>
<td></td>
</tr>
<tr>
<td>Annual Conferences</td>
<td>Teachers, private schools</td>
</tr>
<tr>
<td>ISU alumni</td>
<td>Teachers, ministries of education, nongovernmental organizations</td>
</tr>
<tr>
<td>Published Papers</td>
<td>Teachers, private schools, nongovernmental organizations</td>
</tr>
<tr>
<td>Space Agencies</td>
<td>Teachers, ministries of education</td>
</tr>
<tr>
<td>Text-book Updates</td>
<td></td>
</tr>
<tr>
<td>Annual Conferences</td>
<td>Teachers, private schools</td>
</tr>
<tr>
<td>Online</td>
<td>Teachers, students, parents</td>
</tr>
<tr>
<td>Published Papers</td>
<td>Teachers, private schools, nongovernmental organizations</td>
</tr>
<tr>
<td>Khan Academy</td>
<td></td>
</tr>
<tr>
<td>Annual Conferences</td>
<td>Teachers, private schools</td>
</tr>
<tr>
<td>Online</td>
<td>Teachers, students, parents</td>
</tr>
<tr>
<td>Published Papers</td>
<td>Teachers, private schools, nongovernmental organizations</td>
</tr>
<tr>
<td>Songs and Videos</td>
<td></td>
</tr>
<tr>
<td>Annual Conferences</td>
<td>Teachers, private schools</td>
</tr>
<tr>
<td>ISU alumni</td>
<td>Teachers, students, parents, nongovernmental organizations</td>
</tr>
<tr>
<td>Online</td>
<td>Teachers, students, parents</td>
</tr>
<tr>
<td>Published Papers</td>
<td>Teachers, private schools, nongovernmental organizations</td>
</tr>
</tbody>
</table>
APPENDIX F: RECOMMENDATIONS MATRIX

Table F-1 links the potential product based solutions from section 4.4 with the recommendations that were outlined in Table 4-1. This appendix identifies the requirements that may be met by each solution and is intended to help in the selection of a potential product based solution that may best meet the needs of the target demographic.

Table F-1: Recommendations Matrix

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Workshops</th>
<th>The Space Cycle Game</th>
<th>World Space Week Coordination</th>
<th>On-Orbit Student Competitions</th>
<th>Textbook Updates</th>
<th>Khan Academy Extension</th>
<th>Video Outreach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Includes developing and least developed countries</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Available and designed for all cultures and genders</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>High accessibility with low costs</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Supports guided, hands-on learning</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Provide accessible resources for teachers</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Improve students’ perception of STEM being too difficult</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
### Table F-2: Recommendations Matrix (Contd.)

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Workshops</th>
<th>The Space Cycle Game</th>
<th>World Space Week Coordination</th>
<th>On-Orbit Student Competitions</th>
<th>Textbook Updates</th>
<th>Khan Academy Extension</th>
<th>Video Outreach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Give a proper introduction to each subject, telling the students why the subject matters and careers it enables, and presenting the subjects in the most interesting manner</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Have a formal process to assess student learning and attitude</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Have a defined set of criteria to compare to other existing solutions</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Have a defined, comprehensive evaluation and feedback system</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Provides a system for evaluation and feedback allowing improvement</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Incorporate art as an experience</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Incorporate art as a design process</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
# APPENDIX G: ADDITIONAL RESOURCES

## Table G-1: Additional STEM content resources

<table>
<thead>
<tr>
<th>Institution</th>
<th>Solution/Product</th>
<th>Contact Information/Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rocket Science Tutors</td>
<td>RST Additional 'Class' program and the 'Classroom Manual' containing lesson plans for STEM education</td>
<td><a href="http://www.rocketsciencetutors.com">http://www.rocketsciencetutors.com</a></td>
</tr>
<tr>
<td>mn-stem.com Educational Website</td>
<td>STEM Tool Kit, Multimedia tools for promoting STEM.</td>
<td><a href="http://www.mn-stem.com/">http://www.mn-stem.com/</a> e-mail: <a href="mailto:mde.stem@state.mn.us">mde.stem@state.mn.us</a></td>
</tr>
<tr>
<td>Whitaker Center for STEM Education and Florida Space Research Institute</td>
<td>K-12 teacher professional development program and Programs for advancement of STEM education</td>
<td><a href="http://www.fgcu.edu/WhitakerCenter/">http://www.fgcu.edu/WhitakerCenter/</a></td>
</tr>
<tr>
<td>NSL Satellites Ltd</td>
<td>Low cost technologies for affordable space missions for STEM education, Project Based Learning (PBL) for STEM Enhancement</td>
<td><a href="http://www.nsl-satellites.com">www.nsl-satellites.com</a></td>
</tr>
<tr>
<td>Institute of Education Sciences</td>
<td>PISA(Program for International Student Assessment), TIMSS (Trends in International Mathematics and Science Study)</td>
<td><a href="http://nces.ed.gov/">http://nces.ed.gov/</a></td>
</tr>
<tr>
<td>Institution</td>
<td>Solution/Product</td>
<td>Contact Information/Source</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Center for the Advancement of Science in Space (CASIS)</td>
<td>STEM/Outreach and plans to engage the general public, National competition to grow the largest Sunflower in Space</td>
<td><a href="http://www.iss-casis.org/About/AboutCASIS.aspx">http://www.iss-casis.org/About/AboutCASIS.aspx</a></td>
</tr>
<tr>
<td>Program in Education, Afterschool and Resiliency, McLean Hospital and Harvard Medical School</td>
<td>Informal Science in 'After School Programs'</td>
<td><a href="http://www.pearweb.org/">http://www.pearweb.org/</a></td>
</tr>
<tr>
<td>The University of Texas at El Paso</td>
<td>Texas PreFreshman Engineering Program (TexPREP) -- Identify and motivate high-achieving middle and high school students with interests in STEM.</td>
<td><a href="http://research.utep.edu/Default.aspx?alias=research.utep.edu/texprep">http://research.utep.edu/Default.aspx?alias=research.utep.edu/texprep</a></td>
</tr>
<tr>
<td>Pan American Center for Earth and Environmental Studies</td>
<td>Activities with space-oriented themes for STEM awareness among K-12 students, especially those with minority and socio-economically disadvantaged backgrounds -- CricketSat electronic telemetry device activity, Protein Crystal Growth experiment, Rover design competition</td>
<td><a href="http://research.utep.edu/Default.aspx?alias=research.utep.edu/paces">http://research.utep.edu/Default.aspx?alias=research.utep.edu/paces</a></td>
</tr>
<tr>
<td>American Indian Science and Engineering Society</td>
<td>STEM Awareness and Retention Initiative through Science and Engineering Fair and EXPO, Workshops on The Scientific Method</td>
<td><a href="http://www.aises.org">http://www.aises.org</a></td>
</tr>
<tr>
<td>Science and Engineering Research Council, Dept. of Science and Technology</td>
<td>National Science Olympiad Programme covering Mathematics, Physics, Chemistry and Biology for Pre-University students. Kishore Vaigyanik Protsahan Yojana - Program to encourage students of the Science, Engineering and Medicine to take up careers in research in these fields.</td>
<td><a href="http://www.serc-dst.org">http://www.serc-dst.org</a></td>
</tr>
<tr>
<td>Institution</td>
<td>Solution/Product</td>
<td>Contact Information/Source</td>
</tr>
<tr>
<td>-----------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------</td>
</tr>
<tr>
<td>The George Lucas Educational Foundation</td>
<td>Reshaping Learning from the Ground-up</td>
<td><a href="http://www.edutopia.org/future-school">http://www.edutopia.org/future-school</a></td>
</tr>
<tr>
<td>Japan Science and Technology Agency</td>
<td>Establishment of Super Science High School for improving Science education</td>
<td><a href="https://ssh.jst.go.jp/">https://ssh.jst.go.jp/</a></td>
</tr>
<tr>
<td>Challenger Center for Space Science Education, Virginia</td>
<td>Educational material (Community-based programing, teacher and student mentorship, tutorials and afterschool sessions, summer camps, family science nights, and professional development).</td>
<td><a href="http://www.challenger.org/">http://www.challenger.org/</a></td>
</tr>
<tr>
<td>Lincoln Interactive</td>
<td>Provides Online curriculum and cutting-edge programs for STEM</td>
<td><a href="http://www.lincolninteractive.org/">http://www.lincolninteractive.org/</a></td>
</tr>
<tr>
<td>Rhode Island School of Design</td>
<td>STEAM CLUB for integrating ART+Science</td>
<td><a href="http://www.risd.edu/About/STEM_to_STEAM/">http://www.risd.edu/About/STEM_to_STEAM/</a></td>
</tr>
<tr>
<td>The Lunar and Planetary Institute</td>
<td>Workshops, Art Competitions to promote STEM</td>
<td><a href="http://www.lpi.usra.edu">http://www.lpi.usra.edu</a></td>
</tr>
<tr>
<td>China Quality-Oriented Education Net</td>
<td>Study tutorials for STEM</td>
<td><a href="http://www.chinaszjy.cn/">http://www.chinaszjy.cn/</a></td>
</tr>
<tr>
<td>LJ Create Incorporated</td>
<td>Science Resources for Elementary, Middle and High Schools</td>
<td><a href="http://www.ljcreate.com/">http://www.ljcreate.com/</a></td>
</tr>
</tbody>
</table>