Science, Technology, Engineering, and Mathematics (STEM) can be viewed as an integrating new concept and “an opportunity to collapse the teaching of these subjects individually by using a more interdisciplinary approach to learning” (Dugger, 2010). This paper reports the main results of a study based on 3 categories of country: in the least developed countries where economies start to evolve, mortality has to decrease and equality has to improve, STEM needs to mature; in developing countries, STEM can be seen as a need to drive economic growth; and in developed countries, we observe a lack of interest in STEM education to the benefit of business disciplines. We tend to evolve from linear/local (20th century) to non-linear/global (21st century) approaches, where complexity management becomes a major issue (Boy, 2012). It was clearly identified that creativity cannot be treated separately from STEM, and Arts should be an integrating part of a novel approach called STEAM (Science, Technology, Engineering, Arts and Mathematics). Longer-term socio-technical possible futures should replace short-term financial predictions that currently lead to chaotic economies. From that point of view, space technologies, systems and practices can contribute to improving STEM education technologies, systems and practices. Space is about cognition, innovation and risk taking. We are in a critical age where our civilizations are evolving faster than before due to information technology integration in our lives. We then need to better understand where we are going and invent our future on our planet Earth in the same way as we are exploring how we will be able to live on the Moon or Mars. It is time to go back to goal-driven approaches where visionary ideas should be promoted, explored and developed.

I. INTRODUCTION

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 an 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 space framework is heavily dependent on international cooperation in 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 perceive, comprehend and project new challenges?

This paper is an integration of the results found by the participants to the ISU-SSP12 team project on “what space can contribute to global STEM education”, and preliminary work performed by my graduate students at Florida Institute of Technology and Ecole Polytechnique of Paris on STEM and human-centered design (HCD). We also investigated the integration of Arts into STEM. 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 currently lead to chaotic economies. From that point of view, space technologies, systems and practices can contribute to improving STEM education technologies, systems and practices. Space is about cognition, innovation and risk taking. We are in a critical age where our civilizations are evolving faster than before due to information technology integration in our lives. We then need to better understand where we are going and invent our future on our planet Earth in the same way as we are exploring how we will be able to live on the Moon or Mars. It is time to go back to goal-driven approaches where visionary ideas should be promoted, explored and developed.

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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).

II. WHERE STEM EDUCATION IS TODAY

Of course, we need to make a distinction between least developed, developing and developed countries, when we talk about STEM. For example, in developed countries, loss of good STEM graduates is a general trend. Whereas, developing countries sometimes have insufficient STEM students for the demand and/or poor education systems. Sometimes existing facilities in a country are inaccessible to citizens. Motivation is always at stake. How young people can be inspired to study difficult disciplines such as STEM? The answer is very simple; we need enthusiasm and visionary people who open the way! “We choose to go to the Moon in this decade and do the other things, not because they are easy, but because they are hard; because that goal will serve to organize and measure the best of our energies and skills; because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one we intend to win...” John F. Kennedy said in September 1962. In July 1969, Neil Armstrong stepped on the Moon and came back safe on planet Earth.

Where is our society today? Unlike the sixties where there were several big projects such as Apollo, Concorde, TGV, nuclear power plants and the beginning of the computer industry, and despite the fast growing evolution of information technology, the beginning of the twenty-first century lacks of visions. We are ruled and dominated by finance, which makes us event-driven and reactive instead of goal-driven and intentional. We are always trying to predict what will happen to us, necessarily in the very short term (just because prediction is short-term by definition), and we do not try to investigate possible futures and seriously invest in things that matter to humankind. If we want to motivate young people, it will have to be for great endeavors, and not for money only.

It is amazing to observe that excellent students in mathematics and science are now reluctant to take engineering jobs because they see that they will not use their skills, but management instead, and potentially become servants of finance. In some cases, they are complementing their initial background by an MBA and use their STEM skills and knowledge directly to support finance. We then need to come out from this Catch 22 vicious circle, and start to break free towards human-centered technology development. We believe that space-related activities inspire students and should be better integrated in STEM curricula.

We observe that many students are bored with STEM at school. We know that STEM disciplines are hard, but they should be taught with enthusiasm and creativity. This is why a good mix of STEM and Arts is certainly a solution. Engineering and design should be more integrated. Engineering is about technology; design is about people. Design goes from purposes to means, whereas engineering typically goes from means to purpose. Design is a goal-driven activity: the activity of an architect. Engineering is an event-driven activity because usages of artifacts being engineered are incrementally discovered and technology has to be adapted constantly. Design is a goal-driven activity that takes into account purposes from the very beginning by developing scenarios, evaluation principles and criteria and all kinds of possible simulations.

Human-centered STEM, which could be called STEAM (with an A for Arts), has to evolve. In particular, the twentieth century was the century of Descartes where linear algebra and rationalization were the main assets for developing technology (i.e., we cut the world into pieces, we solve problems locally and most of the time linearly, we reassemble and we manufacture). The twenty-first century will be the century of Leonardo da Vinci where complexity science and creativity will be the main conceptual tools for the development of not only technology, but also organizations and people’s ways of doing things. Our world has become complex not because we have made complicated things, but because we are more interconnected than we have never been. The number of entities and their interconnections makes such complexity, which inevitably needs to be analyzed, understood and mastered. STEAM of the twenty-first century is a giant challenge in front of us. Space can help making education more global, equitable, affordable, creative and attractive. This is why my ISU-SSP12 students coined the slogan, “SPACE: a giant leap for education!”

The gender gap is still a major issue. We observe a lack of role models and peers for females. 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 (Asworthy and Evans, 2001; Carell et al., 2010). The number of female STEM graduates also impacts the graduation rate of other female students (Griffith, 2010). 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. 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).

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 towards the role of caregiver 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).

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. Another side of the financial aspect is the lack of opportunities after graduation. Some developed countries experience “brain drain” in which graduates 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).

Sewell and Shah (1967) stated, “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. In response to this parental pressure, the educational system and human resources in STEM fields are being updated and improved (Guo, 2011).

Summarizing, a list of issues can be drawn:
• Inspiration is lacking (Fewer moon wannabes).
• Appeal/perceived difficulty of STEM disciplines is lacking.
• Interest in STEM versus Business is lacking.
• Young people are less engaged in STEM than their predecessors.
• Technology is perceived as a substitute for effort.
• Curricula are not providing depth to master concepts (especially at the K-12 level).
• We are loosing many university students into STEM programs because of the rigor; they leave in business education where they can work less hard for more money.
• Good STEM students are very disappointed when they become aware of industry requirements that are not at all STEM oriented, and lead towards business management.
• The information age model replaces the industrial age model.

III. WHAT STEM FOR TOMORROW

The twentieth century was concretization of the industrial revolution. The positivist approach prevailed. We cut the world into pieces that could be processed “linearly” and “locally.” The twenty-first century is the revelation of the information age, putting forward “non-linear” and “global” systems. Phenomenology has become a philosophical support to better understand and handle our lives. We are more interconnected. Planet Earth has become a giant village with the emergence of great possibilities, as well as enormous difficulties and challenges. For example, linear algebra, one of main constituency of last century’s mathematics, needs to be augmented and probably subsumed by complexity science. What characterizes our century is hyper-connectivity, networking, complexity, emergence of new properties and practices. Human-computer interaction and human-human interaction via computers are crucial topics. Biology and computer science have become major disciplines putting classical (mechanical) engineering behind. However, if we want to go to Mars, STEM as a whole has to be highly developed.

Designing technology without “designing” organizations and people’s practices is no longer possible. High interconnectivity of current and future socio-technical systems necessarily induces holistic approaches to design and engineering. For that matter, 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 overcome fear of STEM difficulties. STEM disciplines are hard and challenging. They will even be harder and more challenging in the future because our environment is becoming more complex because interconnections between technology, organizations and people are becoming more complex. However, instead of taking this evolution as a roadblock, we need to take it as a challenge that people can overcome.

What is the real challenge? World is becoming more complex, finance-centered and less human-centered. We need to invent a new world where technology, organizations and people could be harmonized. We believe that it starts at school where values are set up. STEM disciplines are not only background for technological development; they contribute to forming sustainable cognitive capabilities for improving situation awareness, decision-making and action taking. However, if there is no creativity nothing can be invented, and today we need to know what the real problems are, state them appropriately and solve them. We need a breed of people who will be able to invent and develop human-centered possible futures. We need to think in terms of STEAM where the “A” for Arts adds the mandatory right-brain contribution to the left-brain contributions that STEM disciplines are traditionally able to bring.

Arts practice can be used as a design framework supporting any creative synthesis activity (Bourganel, 2012). A major component of any design process is a logical decision-making, such as abductive reasoning. Abductive reasoning can be described as guesswork attempts to link a premise and an outcome. Abductive inference was 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). 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 the 2008 conference on risk taking, organized by the Air and Space Academy, it was noted that abduction and design thinking, combined with reasoned choices, was successfully used by Airbus Industrie’s 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 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 storytelling, 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.

Successful hands-on learning is supported by the fully immersive environment that creative work often provides. The Victorian Space Science Education Centre (VSSEC) 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.

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).

IV. SPACE FOR STEM

“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.

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,

Students often lose interest in STEM education because of the disconnect that exists between the STEM curriculum and its future applications. 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.

Space activities and achievements 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).

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; 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 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.

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).

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.

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.

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 towards 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; engage Americans in NASA’s missions (NASA, 2012).

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. 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)

According to ESA 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 towards 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 European Space Education Resource Office (ESERO) leads programs dedicated to supporting teachers. 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.

According to JAXA 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 curricula instead of being proposed as extra-curricular, volunteer-based activities.

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).

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.

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 & 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, schoolteachers, 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 (NNRMS).

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 schoolteachers 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).

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).

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 & 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 nanosatellites. In parallel to the formal studies, students have the opportunity to meet experts from Israel’s space industry and visit aerospace factories (Blizovski, 2006). The students design experiments that are sent to the 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.

In Romania, the Romanian Space Agency (ROSA) coordinates the space program. One of the most inspiring figures for young students is Dumitru Prunariu, Romania’s sole astronaut and Chairman of the UNCOPUOS. 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. 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 Change 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 cosmonauts’ 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.

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 Lunar X PRIZE (X PRIZE, 2012).

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 International Space Station (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 Planetary Society, American Astronomical Society, and Ursa Astronomical Association, have existed for a century or longer in many countries. They share the aim of increasing space awareness and to engage people in active exploration. In this context, the Google LunarX PRIZE is an example of the new projects that specifically aim to promote STEM fields through space. There is a separate section on the Google Lunar X 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.

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

V. CONCLUSION

Current socio-technical issues in the way companies are managed are a very deep problem that will not be solved by cosmetic Band-Aids. 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 the 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 more effective educational programs.

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 for a change to the traditional system. The rationales behind the alternative schools reveal weaknesses in the
traditional system that many people want to change, 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.

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. In order 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 a process would assure the compliance of the material to the curricula, and 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 regular school curricula.

ACKNOWLEDGEMENTS
Many thanks to the ISU SSP12 STEM TP participants Fredrik Bendz Arreestad, Anastasia “Natassa” Antoniou, Eduard Ferrete Aymerich, Yasemin Baydaroglu, Dragos Bratasanu, Sara Bruni, Junli Chen, Alberto De Paula Silva, Nir Emuna, Jessica Flahaut, Jeffrey Flood, Hidemasa Fujita, Idan Gadot, Sreenivasan Garimella, Claas Grohfeldt, James Harpur, Donald Martin William Hemmings, Claude Michel Larocche, Alexandre Lasloup, Haijin Li, Xiuqian Li, David Miles, Kazuyuki Okada, Renate Pohl, Jie Peng, George Calder Potts, Catrina Renaud, Andrea Melissa Reyes, Jan Cor Roos, Hallvard Sanberg Sanja Scepanovic, Vanessa Stroh, Hataio Wang, Yiran Wang, Haruka Yamanouchi, Binglin Xu. This paper is based on the STEM TP report that was produced during ISU SSP12.

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