

INSPIRING THE NEXT GENERATION: THE INTERNATIONAL SPACE STATION
EDUCATION ACCOMPLISHMENTS

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The International Space Station (ISS) has a unique ability to capture the imagination of both students and teachers worldwide. Since 2000, the presence of humans onboard ISS has provided a foundation for numerous educational activities aimed at capturing that interest and motivating study in the sciences, technology, engineering and mathematics (STEM). Over 43 million students around the world have participated in ISS-related educational activities. Projects such as YouTube Space Lab, Sally Ride Earth Knowledge-based Acquired by Middle Schools (EarthKAM), SPHERES (Synchronized Position Hold Engage and Reorient Experimental Satellites) Zero-Robotics, Tomatosphere, and MAI-75 events among others have allowed for global student, teacher and public access to space through student classroom investigations and real-time audio and video contacts with crewmembers. Educational activities are not limited to STEM but encompass all aspects of the human condition. This is well illustrated in the Uchu Renshi project, a chain poem initiated by an astronaut while in space and continued and completed by people on Earth. With ISS operations now extended to 2024, projects like these and their accompanying educational materials are available to more students around the world.

From very early on in the program's history, students have been provided with a unique opportunity to get involved and participate in science and engineering projects. Many of these projects support inquiry-based learning that allows students to ask questions, develop hypothesis-derived experiments, obtain supporting evidence and identify solutions or explanations. This approach to learning is well-published as one of the most effective ways to inspire students to pursue careers in scientific and technology fields.

Ever since the first space station element was launched, a wide range of student experiments and educational activities have been performed, both individually and collaboratively, by all the international partner agencies, National Aeronautics and Space Administration (NASA), Canadian Space Agency (CSA), European Space Agency, (ESA), Japan Aerospace Exploration Agency (JAXA) and Russian Federal Space Agency (Roscosmos), and a number of non-participating countries, some under commercial agreements.

Many of these programs still continue, and others are being developed and added to the stations tasks on a regular basis. These diverse student experiments and programs fall into one of the following categories: student-developed experiments; students performing classroom versions of ISS experiments; students participating in ISS investigator experiments; education competitions; students participating in ISS Engineering Education; Education Demonstrations and Cultural Activities.

This paper summarizes some of the main student experiments and educational activities that have been conducted on the space station.

1. INTRODUCTION

The International Space Station (ISS) continues to captivate the attention of learners, educators, and space enthusiasts by providing unique STEM education opportunities. Millions of students around the world have participated in ISS-related educational activities, taking them on a path to become our future scientists, technologists, engineers, mathematicians, innovators, explorers, and leaders. From programming robots to work on the ISS to investigating jumping spiders in microgravity, learners have made exceptional discoveries in their academic talents.

The ISS' STEM education accomplishments would not have been possible without collaborations between NASA, ROSCOSMOS, JAXA, ESA and the CSA. These partnerships have facilitated engagement in a wide array of STEM disciplines by audiences across the globe, particularly students.

Earth Knowledge Acquired by Middle School Students (EarthKAM), led by NASA, enables students to photograph and examine Earth from the unique perspective of space. JAXA's Try Zero-G serves as a cultural activity to enlighten students and the general public on the differences between Earth and space on physical principles. The Tomatosphere Project, sponsored by the CSA, focuses on the effects of the space environment on the growth of tomato seeds in support of long-duration human exploration and teaching scientific methodology. Led by NASA and ESA, the Synchronized Position Hold, Engage, Reorient, Experimental Satellites (SPHERES) Zero Robotics program takes student-designed satellites to the ISS to compete. The High School Students United with NASA to Create Hardware (HUNCH) program involves students fabricating real-world products for NASA as they apply their STEM skills while working creatively in a team.

In the words of Nelson Mandela, "Education is the most powerful weapon which you can use to change the world." The ISS STEM Education Program has proven to be a valuable asset in motivating and inspiring students, teachers, and space enthusiasts from around the world, as they continue to explore and discover new ways of improving life on Earth today and in the future.

2. ISS EDUCATION ACCOMPLISHMENTS

SPHERES Zero Robotics

Since 2009, Massachusetts Institute of Technology Space Systems Laboratory (MIT SSL) has given access to their research facilities SPHERES on board the ISS under the guise of a competitive game designed for High School students called Zero Robotics (ZR). SPHERES are autonomous free-floating volleyball sized satellites on the ISS (figure 1).

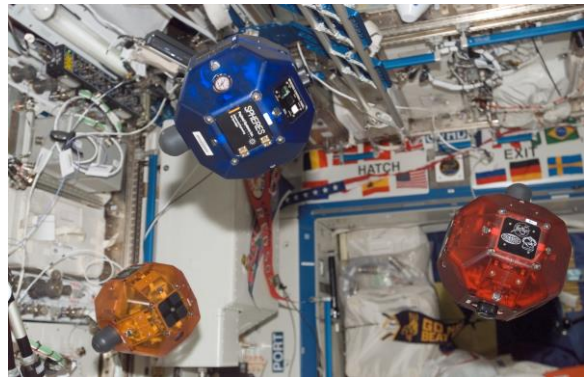


Fig 1: There are three SPHERES on the ISS, two of which are used for ZR (Image courtesy: ESA)

The ZR program is managed and run by MIT with support from partners including TopCoder, Center for Advancement of Science in Space (CASIS), NASA and ESA. Zero Robotics is a coding competition open to all US High Schools and all high schools or equivalent of ESA member states.

Students aged 16 to 18 are required to form structured teams and program the SPHERES which will guide the satellites through a virtual field which changes every year to keep the competition interesting and to give new-comers a level playing field in terms of tactics.

ZR runs from September to December, increasing in complexity as students' progress in the competition. Throughout this period, the teams' codes are run on a simulation platform (figure 2), meaning that schools only need a computer with access to the internet in order to participate. This said, the top scoring teams have the opportunity to test some aspects of their code on a 2D flatbed

platform at MIT in the early phases of the competition.

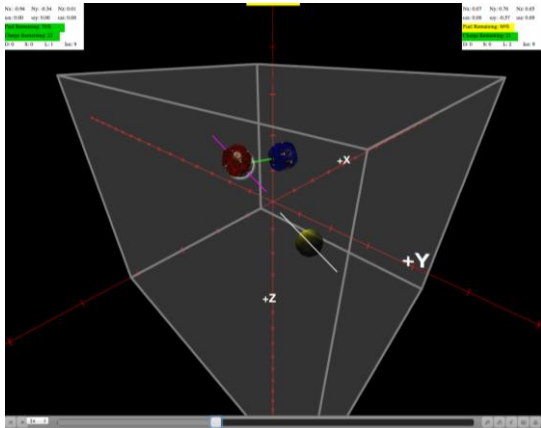


Fig 2: 3D simulation of students' code is done online via a web browser (Image courtesy: ESA)

A key phase in the competition introduced in 2011, when ESA participated for the first time, was the introduction of alliance formation. The alliance of three teams from different states (US) or countries (ESA member states) introduced the students to added complexity of communicating over different time zones, in some cases in different languages, with peers they had never met before.



Fig 3: Alliance of German and Italian students (Brotherhood of Esteemed European Researchers) celebrate winning the ESA finals of the 2012 competition during the live connection with the ISS (Image courtesy: ESA)

Finals of the challenge occur on the International Space Station every January, with several hours of crew time devoted to running the students' code on the International Space Station

using the real SPHERES. On ground, MIT and the ESA Center - ESTEC, are linked up to each other via video conference and to the ISS allowing students to appreciate the true international essence of the challenge (figure 3). Students also participate in robotics activities as well as meet and greet with NASA and ESA astronauts.

The program has been steadily growing in popularity (see table 1) and is ready to expand further, giving direct access to students to the International Space Station.

	2009	2010	2011	2011 ESA pilot	2012	2013
USA	2	24	122		98	108
ESA				21	47	57
Students	13	>200	>1200	>250	>1500	>1500
ISS		10	27	9	27	27
finalist					USA	USA
team #					18	18
					ESA	ESA

Table 1: data of participation in ZR program since 2009

Tomatosphere

Since 2001, an estimated three million students in Canada and the United States have participated in the award-winning Tomatosphere educational project. Tomatosphere fosters student learning about science, space exploration, agriculture and nutrition by giving them hands-on experience with research methodology. The project's hands-on baseline experiment investigates the germination rate of the seeds by providing students with two sets of tomato seeds: one set that has been exposed to space or space-simulated environments, as well as a control group for comparison. Without knowing which set is which, students grow the seedlings in their classrooms, measuring a variety of information about the tomato plants, the germination rates, growth patterns and vigor of the seeds. Each class submits their results to the project's website to be shared with scientists studying horticulture and environmental biology. The blind-study methodology enhances the mystery of the project for each classroom, and adds to the excitement of participating in a real science experiment.



Fig 4: Students take great pride in their Tomatosphere plants, which they may keep at the end of the experiment. Many classrooms report that their students make “space salsa” from the fruits of their labour. (Image Courtesy: Tomatosphere)

A record 17 850 classrooms in Canada and the United States have registered for the 2014-15 school year. The next-generation of budding Tomatosphere student scientists will group 600000 space seeds spent five months aboard the International Space Station, returning to Earth with Canadian astronaut Chris Hadfield in May 2013.

The students become engaged in the hands-on activity and complete the project with a sense of accomplishment of having made a contribution to space science and future space technologies. As international space agencies work towards human missions to the Moon or Mars, it is interesting to note that the astronauts who will one participate in those future missions may be sitting in grade-school classroom today and learning the fundamentals of science. Tomatosphere may be the educational spark that inspires them to reach for the stars.



Fig 5: Canadian astronaut Chris Hadfield displays the seeds he will return to Earth for the Tomatosphere project. (Image Courtesy: Canadian Space Agency/NASA)

Try Zero-G

JAXA started the Try Zero-G program for Asian countries in 2011. Try Zero-G is JAXA's in-orbit educational campaign program to perform simple, yet excellent science experiments proposed by young students, aiming to promote “Kibo”/ISS utilization in the Asia-Pacific region. These experiments were conducted by the crewmembers on board the ISS, to visualize and demonstrate the laws of physics and mysterious phenomenon in micro-gravity. These activities, even though educational in nature, are classified by JAXA as Cultural Activities. They serve to enlighten the students and the general

public about microgravity and human spaceflight. It is also used to demonstrate that space is not only useful for scientists and engineers but also for writers, poets, teachers and artists.

The first Try Zero-G campaign was performed by JAXA astronaut Satoshi Furukawa in "Kibo" September 2011, shown in Figure 6. Ten (10) ideas from three Asian countries were applied and four (4) experiments proposed from Australia, Malaysia and Bangladesh were conducted.



Fig 6: “Conservation of Mass (Bangladesh)” experiment conducted by Satoshi Furukawa (Image Courtesy: JAXA)

The impact of the first Try Zero G was tremendous as the number of applications for the second Try Zero-G Asia campaign, increased to 127 ideas from four Asian countries. Ten (10) experiments from Australia, Malaysia and Pakistan were selected and these experiments were performed by JAXA astronaut Akihiko Hoshide in "Kibo" November 2012, shown in Fig. 7.



Fig 7: “Weight Station (Australia)” and “Hook’s Law in Space (Pakistan)” experiments conducted by Akihiko Hoshide (Image Courtesy: JAXA)

The third campaign was conducted February 2014 by JAXA astronaut Koichi Wakata, shown in Figure 8. Forty-five (45) proposals were submitted from five countries. Among them four experiments were selected and conducted.

A total of 18 experiments have been conducted to date. Participating countries set high valuations on the program because this program can develop an interest in science for young students and a sense of participation in space activities for the people of Asian countries. Considering to the requests by Asian countries, this program has to be continued and also be improved to extend a broader range of people.



Fig 8: “Bernoulli’s principle (Malaysia)” experiment conducted by Koichi Wakata (Image Courtesy: JAXA)

MAI-75

Space Experiment (SE) "MAI-75" ("Spacecraft and modern technologies for personal communication connection") is held in the Russian segment of the International Space Station (ISS RS) since 2005. The experiment consists of developing technology that transmits various types of information that is either pre-recorded or real-time. It also provides timely photos and videos from space on public land user terminals in order to address problems that educational institutions may have that of users of mobile communications and the Internet. The data from the experiment are transmitted in a format SSTV (Slow Scan Television) with the help of amateur radio communication system, the main element of which is the on-board radio KENWOOD

TM D700 transceiver of the "Sputnik" <<RLS "Sputnik">> HAM radio system.

The experiment uses a communication channel to the amateur radio frequencies, which can significantly increase the number of participants in Russia and around the world. The results of the experiment may be received while in the workplace, possible by having receiving-transmitting equipment, amateur radio frequency bands VHF.



Fig 9: Russian cosmonaut Mikhail Tyurin during a communication session with MAI (Image Courtesy: ROSCOSMOS)

During the entire period of this activity 120 sessions were carried out between ISS Russian Segment and MAI Data Reception and Processing Center, each lasting from 9 to 15 minutes. More than 240 photos and videos were taken. After preprocessing, the resulting images were posted on the Internet on a special website, where they can be used by members of the educational community, as well as ordinary users. Additionally, amateur radio receiving points can access ISS streamed information, both on the territory of Russia and internationally.

As a result of the experiment "MAI-75" there was scientific and technical basis created for practical utilization of the ISS RS resources. This was done to prepare specialists in developing the technology and the technical means to ensure communication between students and cosmonauts that can lead to different a forward satellite educational system.

The capabilities of modern information and communication technologies, particularly the Internet, and of the mobile communications operators

enable education program participants to work directly with the general-purpose video equipment deployed on the ISS. Using a Web interface and a special site, the program participants are able to control a digital camera installed on the ISS RS, based on both the Web-posted camera operation schedules and the ISS sub-satellite point movement data.



Fig 10: Centers of data reception from the ISS RS during "MAI-75" experiment sessions. (Image Courtesy: MAI)

Using information from space in the educational process of secondary and higher education system would improve the effectiveness of teaching natural science disciplines cycle, as well as to provide additional public awareness of the status of implementation of space programs.



Fig 11: Sample of image taken from the ISS RS by amateur radio communication channel during the sessions SE "MAI-75." (Image Courtesy: MAI)

Sally Ride EarthKam

One of the longest running investigations on the ISS to target students is an educational project developed by Dr. Sally Ride, the first American woman in space. The Sally Ride EarthKAM (Earth Knowledge Acquired by Middle School Students) has been in operation since Expedition 2 in 2001.



Fig 12: This image shows two students from Sacaton, Arizona who participated in the Sally Ride EarthKam project for three missions. The students are locating areas on a map that were captured by the EarthKAM camera. (Image Courtesy: NASA)

This project allows students and their teachers to select the world's most interesting geological features that are being studied in subjects such as Earth and Space Science, Geography, Geology, Mathematics, Physics, Social Studies. The targets are then submitted over the internet and the EarthKam ground controllers send commands to the camera on-board the ISS. Once the ISS flies over the particular target, the images are taken and then download to the mission control center located at the University of California, San Diego. The students then have access to their images via the Earthkam website.

EarthKam is one of the ISS's global education programs and have reached 292,373 students 5,758 teachers and 64 countries across 6 continents. It serves as an effective educational activity that engages students in their studies of science, technology, engineering and mathematics (STEM). An example of some of the images that

were taken by middle school students across the US are shown in Figures 13 and 14.



Fig 13: This image from NASA's EarthKAM is of the northern end of the Persian Gulf and the broad delta complex of the Tigris, Euphrates, Shatt al Arab, and Karun rivers has captured the arid-looking wetlands of northeast Kuwait (Bubiyah Island) (Image Courtesy: NASA JPL)

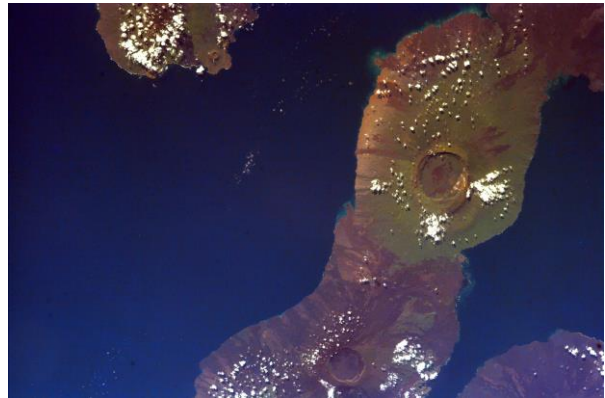


Fig 14: This image of the Galapagos Islands captures two large shield volcanoes on Isla Isabella, the largest and least inhabited island in the Galapagos chain. This image is from NASA's EarthKAM. (Image Courtesy: NASA JPL)

HUNCH

Another way in which students can get involved in ISS education activities is by developing hardware that support the ISS program. One particular project called HUNCH (High School Students United with NASA to Create Hardware) is an innovative program that provides opportunities for

middle and high school students across the United States to design and fabricate cost-effective hardware, soft goods and educational videos that are used in real-world applications for NASA.

Since 2003, 1500 students from 12 states around the US receive hands-on experience and in some cases, flight certification from NASA for developed hardware that supports ISS crewmembers and ground-support personnel. Students are supplied with materials and drawings to produce hardware. During fabrication and upon completion of the design, quality inspection and oversight is provided by professional engineers.

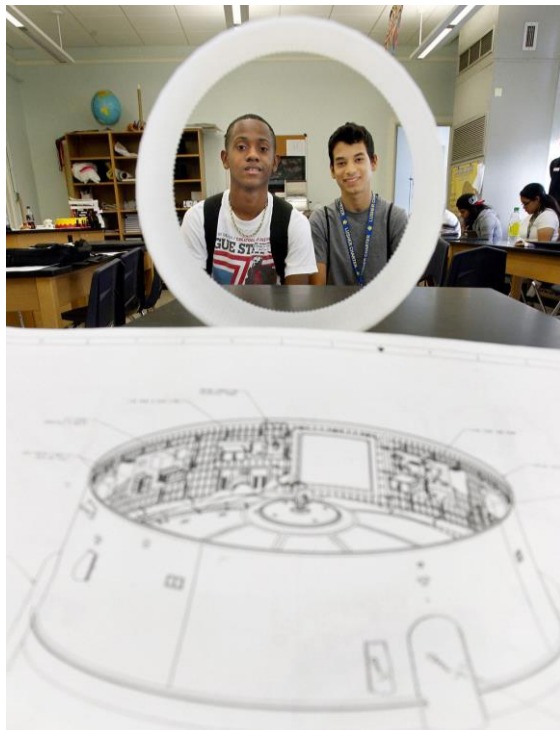


Fig 15: Students with the drawings and finished model of an Ortho Grid, which the class team created. The Ortho Grid is a storage area on the International Space Station. (Image Courtesy: Eliot Kamenitz, The Times-Picayune.)

3. CONCLUSION

At its core, the International Space Station education portfolio strives to allow for participation in support of the ISS mission by the world-wide public, educators and students. Consistent with the goals of each of the ISS Partner Education offices,

projects continue to be developed that promote the STEM fields with the expected outcomes of (1) motivating and inspiring the next generation of scientists, engineers, technologists and mathematicians, (2) attracting and retaining students in STEM disciplines through a progression of education and research opportunities for students, formal and informal educators, (3) identifying opportunities to extend the impact of STEM educational activities to reach more students and (4) building strategic partnerships and linkages that promote STEM literacy through formal and informal educational opportunities. The projects that are highlighted in this paper are just a few examples of the opportunities that are afforded students, globally.

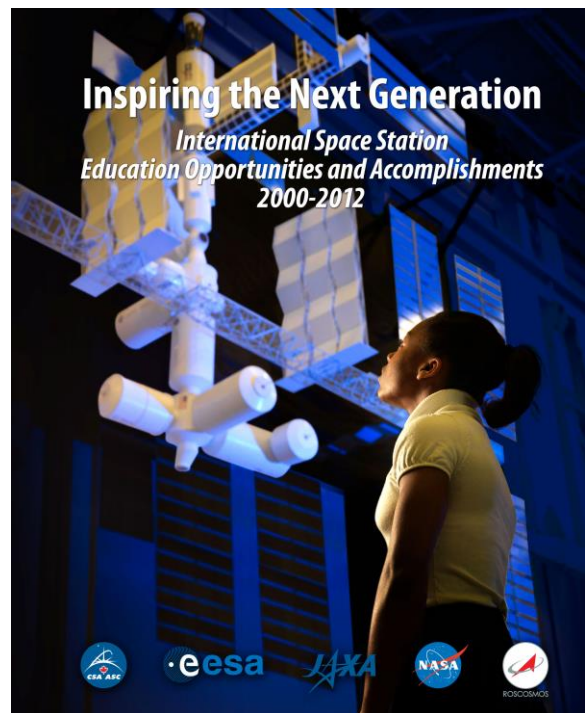


Fig 16: “Inspiring the Next Generation: International Space Station Education Opportunities and Accomplishment, 2000-2012” (Image Courtesy: NASA)

The publication entitled “Inspiring the Next Generation: International Space Station Education Opportunities and Accomplishment, 2000-2012” shown in Figure 16, chronicles all of the projects and activities that have been accomplished in the last twelve (12) years.

Finally, the ISS was not built to conduct education activities but its presence along with that of its crewmembers serves as a unique resource to engage and inspire students, educators and life-long learners through the lifespan of the station.

4. REFERENCES

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