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Thinking Inside the Box: A Hands-on Student Activity for Building a Contamination Containment Glovebox to Encourage Problem Solving in a Collaborative Environment

Elaine Seasly[a]*, Gugu Rutherford[b], Rudo Kashiri[c], Joyce Corriere[d]

[a] *Office of Planetary Protection, National Aeronautics and Space Administration (NASA) Headquarters, 300 E Street SW, Washington, District of Columbia, United States, 20546-0001*, elaine.e.seasly@nasa.gov
[b] *Systems Integration and Test Branch, NASA Langley Research Center, 1 Nasa Dr, Hampton, Virginia, United States, 23666*, gugu.n.rutherford@nasa.gov
[c] *Virginia Space Grant Consortium, Old Dominion University, 600 Butler Farm Rd #2253, Hampton, Virginia, United States, 23666,* rkashiri@odu.edu
[d] *Virginia Space Grant Consortium, Old Dominion University, 600 Butler Farm Rd #2253, Hampton, Virginia, United States, 23666,* jcorrier@odu.edu
* Corresponding Author

Abstract

Engineers from the National Aeronautics and Space Administration (NASA) and education experts from the Virginia Space Grant Consortium (VSGC) partnered together to create a hands-on student activity to teach students about problem solving, working in a collaborative environment, and about the unique career fields of contamination control and planetary protection. The activity focuses on contamination containment gloveboxes, which are sealed containers where operators outside the glovebox can safely manipulate hazardous or contamination-sensitive materials inside the glovebox through glove ports on the container. The activity utilizes common household materials and teams of students work together to design and build a glovebox using the materials provided. Once the glovebox has been constructed, students perform a task under a time constraint by using their glovebox to assemble a puzzle "contaminated" with corn starch. In a post-activity debrief, teams discuss lessons learned such as how the actual built glovebox differed from the sketched design, the challenge of managing a budget for materials, how the team dealt with surprises, and if their glovebox allowed enough room for the operator to perform the task. This activity has been part of VSGC's Virginia Earth System Science Scholars (VESSS) summer academy program for high school students since 2016, and has been an engaging method to teach students teamwork, creativity, hands-on experimentation, communication, and reasoning skills while also teaching them about unique engineering fields such as contamination control and planetary protection.
Keywords: student, activity, collaboration, hands-on, contamination, glovebox

Acronyms/Abbreviations

ARES	Astromaterials Research and Exploration Science
GIDEP	Government-Industry Data Exchange Program
ISO	International Organization for Standardization
ISS	International Space Station
MSG	Microgravity Science Glovebox
NASA	National Aeronautics and Space Administration
STEM	Science, Technology, Engineering, and Mathematics
VSGC	Virginia Space Grant Consortium
VESSS	Virginia Earth System Science Scholars

1. Introduction

Hands-on activities can be a fun and engaging way to teach students about engineering skills such as designing, building, troubleshooting, problem solving, communication, and teamwork. Through these activities, students are allowed to experiment with materials and concepts which can lead to memorable learning experiences. Hands-on activities can also provide mentoring opportunities for engineering professionals to introduce students to unique career fields. For example, the contamination control and planetary protection fields are often disciplines that many students are often not introduced to until they begin working in industry. Contamination control engineering is an important part of aerospace engineering, and ensures the performance of sensitive systems such as optical, electrical, mechanical, and thermal systems are not compromised due to the presence of foreign materials such as particles and molecular films. Similarly, the planetary protection discipline seeks to control contamination of spaceflight hardware to prevent harmful contamination of solar system bodies during exploration, and to prevent harm to Earth's biosphere when returning extraterrestrial materials to Earth from solar system exploration. To provide an opportunity to teach high school students about these unique career fields, contamination control and planetary protection engineers at the National Aeronautics and Space Administration (NASA) teamed together with teaching and education experts at the Virginia Space Grant Consortium (VSGC) to create a hands-on student learning activity. The challenge was to develop an activity that taught a specific aspect of contamination control and planetary protection, could be taught in a few hours, utilized inexpensive common household materials, and was conducive to students working in small teams. The team determined that a contamination containment glovebox would not only provide an example of a device used in the contamination control and planetary protection industries, but would also allow the students to design their own prototype and perform a challenging task using their design.

1.1 Contamination Containment Gloveboxes

Contamination containment gloveboxes are a type of separative device that allow an operator to perform a process without being exposed to the process. "Separative devices provide assured protection in varying levels by utilising physical or dynamic barriers, or both, to create separation between operation and operator. Certain processes may require special atmospheres to prevent degradation or explosions [1]." The process is enclosed in a container or "box" and the operator manipulates tools and materials by wearing gloves that are securely sealed to the container via gloveports. Often, gloveboxes have viewing ports or windows for the operator to visually observe the operation. Gloveboxes are utilized in the contamination control and planetary protection disciplines to limit contamination of processes and perform contamination-sensitive experiments. Specifically in the aerospace industry, gloveboxes are used to manufacture sensitive components and space flight hardware, and to perform experiments. Gloveboxes are even used aboard the International Space Station (ISS) to conduct experiments in microgravity. The Microgravity Science Glovebox (MSG) (Fig. *1*) "…provides a safe environment for Space Station crew to conduct research with liquids, flames, and particles used as a part of everyday research on Earth. Built-in gloves attached directly to the facility doors allow crew to safely manipulate samples inside the sealed facility, and side ports on the Glovebox permit crew to set up and manipulate investigation equipment inside [2]." Gloveboxes are critical in studying materials returned from space such as samples from Earth's moon, asteroids, comets, and in the future, samples returned from Mars. For example, lunar samples from the Apollo missions are stored in the Astromaterials Research and Exploration Science (ARES) Division at NASA's Johnson Space Center in Houston, and gloveboxes are utilized to study the samples (Fig. 2).

Fig. 1. NASA Astronaut Peggy Whitson Works Inside the Microgravity Science Glovebox. (Credit: NASA)

Fig. 2. Andrea Mosie (left) and Jerome Hittle, Scientists at the Johnson Space Center, Examine a Lunar Rock Sample from the Apollo 15 Mission in a Glovebox. (Credit: NASA)

Gloveboxes have a direct connection to the aerospace industry, are key devices in contamination control and planetary protection, and are involved in interesting science experiments. For these reasons, the contamination containment glovebox was chosen as a topic for a hands-on student activity for the Virginia Earth System Science Scholars (VESSS) program.

1.2 The Virginia Earth System Science Scholars (VESSS) Program

The VESSS Program has been offered by the VSGC since 2015 to Virginia high school junior and senior students. The program consists of an interactive, semester-long on-line science, technology, engineering, and mathematics learning experience to engage students in NASA's satellite missions designed to improve understanding of climate change and its global impacts [3]. Upon successful completion of the on-line course, high performing students are invited to a seven-day, residential summer academy at NASA Langley Research Center in Hampton, Virginia. The VESSS Program is free to students, allowing students throughout Virginia (Fig. 3) to participate regardless of economic status. Table 1 provides the student demographics of the VESSS Summer Academy over the past six years.

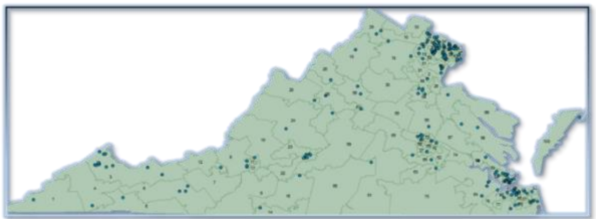

Fig. 3. Virginia Map of VESSS Student Distribution. (Credit: VSGC)

Table 1. VESSS Summer Academy Student Demographics

	2016	**2017**	**2018**	**2019**	**2020***	**2021***
Total Students	69	52	85	69	84	82
Male (%)	54	37	35	36	38	38
Female (%)	46	63	65	64	62	62
Under-represented Minorities (%) *(Self-reported)*	15	23	21	17	14	16
*Virtual academies.						

Students selected to participate in the Summer Academy are immersed in the design of a hypothetical mission to study one of the Earth's major spheres and how the spheres are interconnected. The Academy divides the students into four teams each addressing a real-world scenario relating to one of the four major spheres: Atmosphere, Biosphere, Hydrosphere, and Lithosphere. Scholars work under the mentorship of scientists, engineers, and technologists from NASA, other US Government agencies, academia, and industry to examine state of the art knowledge on issues such as precipitation in clouds, climate zone changes, sea level changes and analyzing ground subsidence of volcanic activity as described in the 2018 Decadal Survey [4]. The student teams design their own satellite mission, including mission goals and science objectives, science instruments and measurements, launch vehicle and orbit requirements, and data analysis. At the culmination of the summer academy, students present their mission design concepts to a panel of NASA and industry experts.

The Summer Academy cultivates students for entry into the 21st-century Science, Technology, Engineering, and Mathematics (STEM) workforce through the development of skills such as critical thinking, technical writing, data analysis, and inquiry-based problem solving as well as learning soft skills such as communication, collaboration, and adaptability. One of the highlight activities of the Summer Academy is the Contamination Containment Glovebox Activity, which provided the opportunity for students to work in teams on the second day of the academy. By providing an interactive hands-on activity early in the week, students had the opportunity to form team relationships early in the seven day course.

1.3 Activity Overview

Background information in the form of a narrative engineering story was provided to the students to introduce the Contamination Containment Glovebox Activity, communicate the problem to be solved, the requirements, and the activity goal. Students were told they must design a glovebox using a list of available materials, but were not given specific information on what would be built inside the glovebox after it was completed. Students were also given a budget with a fixed price for purchasing the initial kit of materials and a purchase list for additional materials available. Finally, evaluation metrics were provided so that students could determine how to maximize their design to gain the most evaluation points. Students knew they would be evaluated on how well they could assemble something inside their glovebox (although they did not know the exact object to be built), that the built item needed to be clean (hinting that there would be contamination), and extra points could be gained for finishing early and within the budget. A summary of the learning concepts the glovebox activity provided the students and the learning objectives are provided in Table 2.

Table 2. Glovebox Activity Concepts and Learning Objectives

Concepts Provided to Students	Learning Objectives
Technical requirements are provided but not all information is known.	Introduces students to real-world situations of having to design around incomplete information.
A list of written technical requirements is provided.	Teaches students to carefully read through the list and understand the requirements and to ask questions for clarification.
One hour of planning and sketch time allowed before physical materials provided.	Teaches students to talk through options as a team and to sketch out initial design ideas on paper before going straight to the hardware build phase.
List of materials, material costs, and team budget provided.	Introduces students to financial planning for the project and to anticipate what materials may be needed to fit within cost constraints.
Evaluation metrics of how complete an object could be built inside the glovebox, object cleanliness, delivery schedule, and budget.	Allows students to learn to account for different metrics of evaluation and to plan their design to maximize evaluation metrics.

2. Materials

The Contamination Containment Glovebox Activity was designed to utilize common household materials. This helped to keep the material investment cost to the VESSS Program low, allowed for easy replenishment or substitution of materials as needed, and also made the activity accessible if students wanted to repeat the activity at home, their school, or share in other community activities after the VESSS Summer Academy. A list of the types of materials needed for the activity are provided in Table 3, and similar materials may be used. Table 4 lists the materials that are provided to each student team as an initial kit of materials (Fig. 4). Students are then able to utilize their budget to purchase duplicate materials for the kit, or the additional materials listed in Table 5. Since students do not know the object to be assembled in the glovebox, they have to balance their budget and design with unknown information, which is a common situation in real-world engineering.

Table 3. Glovebox Activity Material Categories

Type of Materials Needed for the Activity	Example Materials Provided
Structural support materials	Wooden craft sticks, plastic straws
Binding and joining materials	Paper masking tape, clear packaging tape
Enclosure materials	Aluminum foil sheets, plastic bags
Materials to support operations inside the glovebox	Small flashlights, plastic gloves, facial tissues

Table 4. Materials Provided in Initial Kit

Quantity	Item(s)	Dimensions (inches)
1	Pair of gloves	N/A
6	Wooden craft sticks	4.5 x 0.375
4	Aluminum foil sheets	13.39 x 10.75
1	Clear plastic bag	11.5 x 5.0
6	Plastic bendy straws	9
1	Work surface – metal baking sheet	9.75 x 15
1	Flashlight	5.5 inches long

Fig. 4. Prepared Glovebox Activity Kits. (Credit: VSGC)

Table 5. Additional Materials Available

Quantity	Item(s)	Dimensions (inches)
1	Pair of gloves	N/A
1 strip	Masking tape	12 inches long
1 strip	Clear packing tape	12 inches long
½ pack	Facial tissue	N/A
Full pack	Facial tissue	N/A

3. Activity

The Contamination Containment Glovebox Activity is divided into three phases: planning and design, execution, and post-activity debrief and results. During the planning and design phase, the stage is set for the activity by providing students with background information and activity requirements. Students are then given an hour to discuss and sketch their design. During the execution phase, activity materials are provided to the students, and the students construct their glovebox and complete the build of the mystery object. In the post-activity debrief and results phase, activity mentors discuss with the students what went well, what issues arose, and the results of the team scores based on the evaluation metrics.

3.1 Planning and Design Phase

During this phase, students in the VESSS Summer Academy were divided into teams of three to five students. Students were presented a brief background on contamination containment gloveboxes and how they are used in the aerospace industry by NASA engineering mentors (Fig. 5). Students were also provided an introduction to the activity, the goals, constraints and requirements of the activity, the list of materials that would be available, the time schedule for completing the activity, and the performance metrics that would be used to evaluate the performance of their glovebox design. Students were given a mock budget of $300 to cover the investment cost of their kit ($100) and any additional materials they wished to purchase during the activity. During the design phase, most students identified and budgeted for the additional materials they would need to complete the activity.

Fig. 5. NASA Mentors Dr. Elaine Seasly (left) and Dr. Gugu Rutherford (right) Introduce VESSS Students to the Contamination Containment Glovebox Activity. (Credit: VSGC)

Students were told they would build an object inside their glovebox once the glovebox was constructed, but were not told the identity or characteristics of the object. Students were given one hour to work in their teams to discuss the activity and their ideas (Fig. 6), sketch their glovebox designs and ideas (Fig. 7), and plan for the build of their glovebox.

Fig. 6. Students from the 2018 VESSS Summer Academy Work on Their Glovebox Design. (Credit: VSGC)

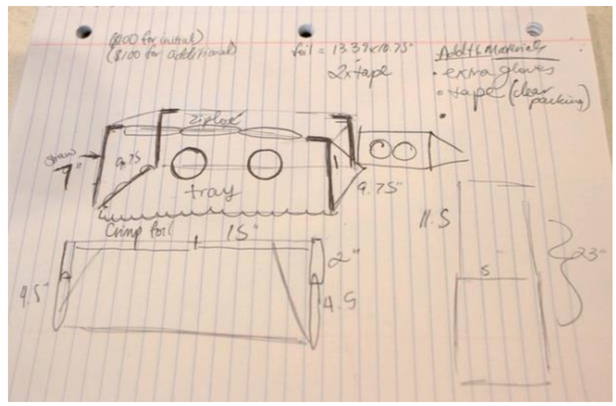

Fig. 7. A VESSS Student Team's Glovebox Design. (Credit: VSGC)

3.2 Execution Phase

Once the hour-long planning and design phase was complete, student teams were issued their glovebox material kits. A timer was started, and students had one hour to complete the build of their glovebox (Fig. 8). Students were able to utilize their mock budget to purchase additional materials as needed. A team of interns also supported the activity by handing out materials, answering questions of students, and performing all material cutting activities (Fig. 9). Students learned that they needed to give interns very specific instructions for cutting materials to the requested shape or length to achieve the desired outcome.

Fig. 8. VESSS Students Constructing a Glovebox. (Credit: VSGC)

Fig. 9. VESSS Student Intern Support. (Credit: VSGC)

An additional opportunity was provided to teach students about material supply chain issues in industry and dealing with surprises. The Government-Industry Data Exchange Program (GIDEP), "is a cooperative activity between government and industry participants seeking to reduce or eliminate expenditures of resources by sharing technical information [5]." Notifications and reports about non-conforming items or problem products are sent through the GIDEP network. This system alerts users of material and product issues so they can take corrective action before major anomalies appear in their systems that may utilize these materials or products. During the lecture portion of the VESSS Summer Academy, NASA engineers provide an overview of GIDEP. Approximately 30 minutes into the build phase of the Contamination Containment Glovebox Activity, a "GIDEP alert" is issued for one of the types of tape used in the glovebox. If students used the tape, they were instructed to immediately remove the tape and replace it with the alternative tape (Fig. 10). Student teams had to utilize their budget to obtain the alternative tape if they had not procured it earlier, or if they no longer had budget remaining, utilize the materials they had on-hand to complete their glovebox. A video showing several GIDEP alert scenarios for the Contamination Containment Glovebox Activity is available at the following link: https://www.youtube.com/watch?v=gxSNtTD9qUU.

Fig. 10. GIDEP Alert Instructing Students to Remove Clear Packing Tape from Their Designs. (Credit: VSGC)

After completion of the one hour build phase, student teams were issued a sealed mailing envelope, which was placed inside the glovebox. Each team selected one team member to be the operator and insert their hands inside the plastic gloves attached to their glovebox (Fig. 11, Fig. 12). Teams were instructed to open their envelopes and begin assembling the mystery object inside the glovebox. Upon opening the envelope, students found the object was a puzzle that had been "contaminated" with corn starch (Fig. 13). Students were given 20 minutes to try to clean and assemble their puzzle while operating within their glovebox. Students that had planned ahead and included facial tissues inside their glovebox had the ability to wipe their puzzle pieces clean. All assembly took place on a single sheet of paper lining the bottom of the glovebox, and when students had felt their puzzles were complete, had to slide their completed puzzle out of the glovebox on the sheet of paper while attempting to keep the majority of the corn starch inside the glovebox. Some teams were able to complete the task (Fig. 14), while others found their glovebox design was unable to maintain structure throughout the activity (Fig. 15). Even when gloveboxes failed to remain intact, VESSS Students were always able to take it in stride and find not only the technical lessons of the activity, but the positive team building through the situation as well.

Fig. 11. VESSS Students Performing Tasks Inside Their Glovebox. (Credit: VSGC)

Fig. 12. Another VESSS Student Team Performing Tasks Inside Their Glovebox. (Credit: VSGC)

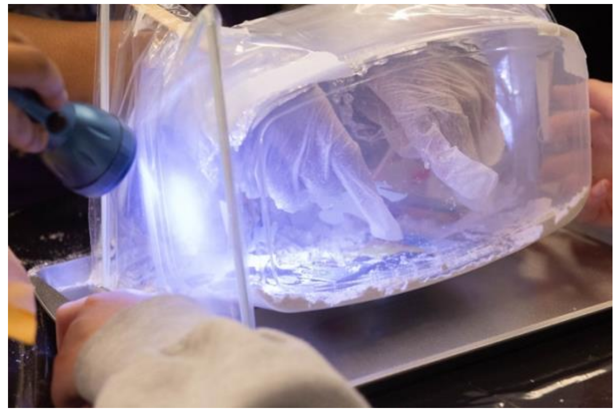

Fig. 13. Hardware "Contamination" of Corn Starch in the VESSS Activity. (Credit: VSGC)

Fig. 14. A Completed Puzzle as Part of the VESSS Contamination Containment Glovebox Activity. (Credit: VSGC)

Fig. 15. VESSS Students Discussing Their Glovebox Situation. (Credit: VSGC)

Once student teams had completed the assembly of their puzzle and removed it from their glovebox, the NASA mentors evaluated the puzzle and assigned points according to the evaluation metrics provided to the teams. Puzzles were judged and awarded points for the percentage of the puzzle completed, the cleanliness of the final puzzle, and if the puzzle was completed before the end of the build period. Also, additional points were awarded if the team finished early. If the team had any remaining budget, they were awarded points equivalent to 10% of the remaining dollar value.

3.3 Post-Activity Debrief and Results Phase

After the activity had concluded and materials and work areas were cleaned, the VESSS Summer Academy re-convened to discuss the activity in a post-activity debrief. The purpose of the debrief was to allow teams to discuss what went well, what did not go well, lessons learned, and areas for improvement in the larger group setting. During the activity, teams mostly focused on their own team, and the debrief was an opportunity for students to communicate with the entire academy audience. The post-activity debrief questions and discussion topics listed in Table 6 were provided to help encourage student teams discuss lessons learned. Some lessons learned offered by the students included how the actual built box differed from the sketched design, the challenge of managing a budget for materials, how the team dealt with surprises, and if their glovebox allowed enough room for the operator to perform the task. This allowed the students to evaluate the performance of their design, determine improvements, identify similarities and differences between their design and those of other teams, and to identify possible alternative approaches. Finally, the evaluation metrics were announced for each team which allowed the teams to recognize their accomplishments within the group (Fig. 16).

Table 6. Post-Activity Debrief Questions and Discussion Topics

• Discuss how creating designs “on paper” is useful for communicating ideas, and how this process can take place months before actual parts are available for engineering designs. • What were the differences between the paper design the teams sketched at the beginning of the activity and the actual design created? • Discuss how companies have to cover the cost to rework parts when problems (such as GIDEP alerts) are discovered. • Did the team’s operator have enough room to easily clean and assemble the puzzle inside the glovebox? Why or why not? • Did any teams realize other materials provided could be utilized, such as the plastic kit supply box and the plastic bags that store the kit materials? • Not all puzzles were the same, and some were more difficult with more intricate designs that others. Discuss how this is representative of real-world situations in engineering. • Parts can be delivered contaminated, just like the puzzles were delivered in sealed envelopes that had corn starch inside. Discuss the real-world examples of this.

Fig. 16. VESSS Students Celebrating Their Results. (Credit: VSGC)

4. Conclusions

The Contamination Containment Glovebox Activity has been a part of the VESSS Summer Academy since 2016 and has introduced to students an important device in the contamination control and planetary protection disciplines while providing a hands-on activity to teach students teamwork, creativity, experimentation, communication, and reasoning skills. The activity provides students the opportunity to work in teams early in the week-long Summer Academy, and helps in forming relationships early in the week. Students not only learn technical skills, but also find the activity fun and entertaining, and it is always a highlight of the Summer Academy experience.

NASA is currently exploring ways to reach more students beyond the VESSS Summer Academy with the Contamination Containment Glovebox Activity. The goal is to offer the teaching materials and activity guides online in the future so that teachers from anywhere can access the material and teach the activity in their local schools. Video recordings, online activities, and other media may be generated and offered to teachers to help enhance the student learning experience.

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