



# Veteran Education Transfer Plan Cover Sheet

Title of ETP	<b>Instruction through Architecture</b>
Name of IISME Fellow	<b>James C. Gaub</b>
Fellow's year-round email	<b>gaub_cory@cupertino.k12.ca.us</b>
Sponsor Company	<b>NASA Ames Research Center</b>
Name of Mentor	<b>Denise Kiser</b>
National Board Certificate Area	<b>Career and Technical Education</b>
<p>I, the IISME <b>Fellow</b> named above, affirm that the ETP I am submitting is my own work, that I acknowledged sources where appropriate, and that I avoided including any proprietary information of the Sponsor Company. By my submission I am assigning to IISME my entire copyright in the ETP. I understand IISME is simultaneously granting me a license to use the ETP for pedagogical purposes.</p>	
<hr style="width: 50%; margin: 0 auto;"/> Signature	<hr style="width: 50%; margin: 0 auto;"/> Date

Category: <b>Data Based ETP</b>	<i>Curriculum</i> Subject: <b>Math</b> Science    Technology    _____ Level: <b>Elem</b> - <b>Middle</b> High    Other <i>Staff Development</i> <i>Describe</i> _____ <i>Other</i> <i>Describe</i> _____
Objectives	Teaching objectives include increased teacher knowledge and ease of acquisition regarding effective science and mathematics instructional resources. Student objectives include further understanding of mathematics in classroom and global contexts, advancement of student performance in geometric applications, and facilitation of student interest in math and science career pursuits.

<p>Abstract (50 words or less)</p>	<p>The project will take the form of action research wherein the teacher will participate as researcher to inform instructional practices, and further student performance in science and mathematics. An established need exists for increased student achievement and understanding in science and math, specifically geometric applications within mathematics. Baseline data of current student performance in geometry will be measured with appropriate and specific metrics. After a results analysis is performed, a series of strategically designed instructional lessons will be implemented to improve student performance in targeted areas of need. A mid-point growth measure will be used to determine student progress performance. An additional metric of student performance will be applied to determine and measure student results after the instructional treatments are provided. Any needed remediation and/or further assessment in areas of poor performance will be administered. The final steps will include evaluations and reporting student results-analysis and research process to colleagues and IISME.</p>
<p>Describe how your ETP aligns with the National Board Standard stated in your proposal.</p>	<p>National Board for Professional Teaching Standards  Career and Technical Education Standards  <u>Standard XI: Collaborative Partnerships</u>  Accomplished career and technical educators work with colleagues, the community, business and industry, and postsecondary institutions to extend and enrich the learning opportunities available to students and to ease school-to-work transitions.</p> <p>Over the next decade an entire generation of scientists and mathematicians will retire – a large gap in expertise will be left in the wake of this global trend. In order to dynamically advance knowledge, understanding, and strategic methods in science, math and technology learners in these fields will need to be trained and well equipped with greater efficacy than ever before.</p> <p>NASA has pioneered and championed exceptional advances in education, science, math, and technology only as NASA can over the past half-century and now stands poised to transport us forward into, and beyond the next.</p> <p>Recent customized curriculum development with NASA will provide applications for educators to promote interest and advances in mathematics and science through effective instructional design, and best practices that brings forward the highest results from teachers and students. The ETP aligns well with stated National Board Standard. The genesis and target-aim of the ETP were developed through direct working partnerships with NASA educators, scientists, engineers, and management. The primary goals of the ETP are rooted in the enrichment of student learning opportunities, and these essential collaborative partnerships.</p>

Describe the connection between your ETP and the Summer Fellowship.	As an IISME Fellow serving as a curriculum developer for NASA Ames Research Center I designed middle school mathematics curriculum to be used by the NASA Education Program. The curriculum is based on the NASA Personal Satellite Assistant (PSA), an autonomous spherical robot that will be used by astronauts onboard the International Space Station (ISS). The standards-based lessons and investigations will teach Geometric concepts in volume and surface area related to the packaging of the PSA. The lesson series is a component in a complete suite of lessons based on mathematic and scientific principles found in Geometry and Physics. A NASA Connect instructional film will be developed as part of the total project. Public Broadcasting Station will broadcast a television special about the autonomous PSA in a PBS learning series.
Growth-Measurement Devices	To measure student performance a collection of data sources will be acquired for analysis. Pre-performance measures will include California State Standardized Test results, and a standardized teacher-created baseline measurement in Geometry (Surface Area and Volume). Duplicate mid-point and end-point measurements in Geometry (Surface Area and Volume) will be utilized. An ongoing anecdotal records journal will be maintained throughout the process. The records journal will be coded for analysis as a final data source of student performance over time. Individual data sources and metrics will together present a complete diagnostic of student growth.
Resources Needed	Materials required for implementation include standards-based mathematics lessons and curriculum supplies, California State Standardized Test results, standardized teacher-created baseline, mid-point, and end-point growth performance metrics, observational/anecdotal records journal.
Evaluation/Assessment Measures Used	California State standardized test scores, standardized teacher-created baseline, midpoint, and endpoint growth performance metrics, anecdotal records journal, mathematics inter-curriculum assessment measurements.
Formatting specifications	PC ____ or Mac__ <b>X</b> __ <b>(Must be in Word or Text Format)</b> Software used __ <b>NA</b> _____
Submitted Copy	Soft and hard copy due to peer coach by the end of the summer fellowship. Also, a copy of the cover sheet signed by a school site administrator submitted to IISME Oct.1, 2003 to receive \$300 grant.

I, the **Mentor** named above [please select one of the following],

- have read the attached ETP, and my comments, if any, appear below.
- have read the attached ETP, and, as outlined in the IISME-Company Fellowship Agreement, have reviewed it on behalf of the Sponsor Company, and have determined that the ETP does not contain any Sponsor-proprietary information. My additional comments, if any, appear below.

Comments:

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Signature

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Date

**Administrator's** comments:

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Signature

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Date

*Instruction*

*through*

*Architecture*

Training & Curriculum in Mathematic Applications for Strategic Support of the Personal Satellite  
Assistant & the International Space Station

**Industry Initiatives for Science and Math Education**  
An IISME Educational Transfer Plan

Prepared by Cory Gaub

IISME Fellowship – NASA Ames Research Center  
NASA Educational Technology  
2003

National Board for Professional Teaching Standards  
**Career and Technical Education Standards**

Standard XI: Collaborative Partnerships

Accomplished career and technical educators work with colleagues, the community, business and industry, and postsecondary institutions to extend and enrich the learning opportunities available to students and to ease school-to-work transitions.

## **Teaching Outcomes**

Teaching outcomes include increased teacher knowledge and ease of acquisition regarding effective science and mathematics instructional resources. Student outcomes include further understanding of Mathematics in discrete and global contexts, advancement of student performance in Geometric applications, and facilitation of student interest in math and science career pursuits.

## **Abstract**

### **Rational**

Research indicates support for the development of these materials which correlates with the evident need for further development of student understanding in science and mathematics, specifically geometric applications. A paramount and more expansive need exists as well, which is to facilitate overall student interest in mathematics and science to promote interest and pursuit in math and science careers. Over the next decade an entire generation of scientists and mathematicians will retire – a large gap in expertise will be left in the wake of this global trend. In order to dynamically advance knowledge, understanding, and strategic methods in science, math and technology learners in these fields will need to be trained and well equipped with greater efficacy than ever before.

NASA has pioneered and championed exceptional advances in education, science, math, and technology only as NASA can over the past half-century and now stands poised to transport us forward into, and beyond the next.

Recent customized curriculum development with NASA will provide applications for educators to promote advances in mathematics and science through effective instructional design, and best practices, that brings forward the highest results from teachers and students.

### *Design*

The inquiry based mathematics curriculum is effectively designed for implementation and dynamic application. Crafted and customized specifically for the NASA

Education Program, the curriculum framework maintains a fluid adaptability for a variety of solution-needs applications.

The project will take the form of action research wherein the teacher participates as researcher to further student performance in science and mathematics. An established need exists for increased student achievement and understanding in science and math, specifically geometric applications within mathematics. Baseline data of current student performance in geometry will be measured with an appropriate and specific metric. After a results analysis is performed a series of strategically designed instructional lessons will be applied to improve student performance in target areas of need. A mid-point growth measure will be implemented to determine student progress performance. An additional metric of student performance will be applied to determine and measure student results after the instructional treatments are provided. Any needed remediation and further assessment in areas of poor performance will be administered. The final steps will be to analyze and report student results-analysis, and research process and results to colleagues and IISME.

#### *Materials & Measurements*

Materials required for implementation include Mathematics Curriculum Suite developed for NASA Personal Satellite Assistant (PSA) Project; student California State Standardized Test results; teacher created baseline, mid-point, and end-point growth performance metrics; observational/anecdotal records journal.

#### *Assessment Metrics*

To measure student performance a collection of data sources will be acquired for analysis. Pre-performance measures will include California State Standardized Test results, and a standardized teacher-created baseline measurement in Geometry (Surface Area and Volume). Duplicate mid-point and end-point measurements in Geometry (Surface Area and Volume) will be utilized. An ongoing anecdotal records journal will be maintained throughout the process. The records journal will be coded for analysis as a final data source of student performance over time. Individual data sources and metrics will together present a complete diagnostic of student growth.

#### *Project base*

The curriculum suite is based on the NASA Personal Satellite Assistant (PSA), an autonomous spherical robot that will be used by astronauts onboard the International Space Station (ISS). The curricular lessons and investigations will teach geometric concepts in surface area and volume related to the safe design, assembly, and functionality of the robotic PSA. A *NASA Connect* instructional film will be developed as part of the curriculum suite that includes other lessons on micro-gravity physics and systems onboard the ISS. A final televised learning component will complete the educational project. PBS will broadcast a television special about the autonomous PSA as part of NASA Education and a Public Broadcasting Station learning series.

*NASA Educational Technology Mathematics Curriculum*

*~ Content & Design ~*

- Main Lesson Concept
- Scientific Question
- Instructional Objectives
- National Standards & Benchmarks
- Misconceptions
- Prerequisite Concepts
- Major Concepts
- Suggested Timeline
- Equipment & Materials

*Engage*.....*anticipatory set*

*Explore*.....*inquiry, observation*

*Explain*.....*data justification*

*Extend/Apply*.....*performance task*

*Evaluate*.....*assessment application*

**Lesson 1:           Surface Area Nets & Orthographic Mapping**

**Lesson 2:           Volume of Rectangular Prisms and Cubes**

**Lesson 3:           Surface Area & Volume Formula Applications**

**Lesson 4:           Dimensional Change Effects on Surface Area and Volume**

**Metrics:           Evaluative Rubric Criteria Guide**

## **Curriculum Framework & Road Map**

- *Concepts shown are lesson-specific. Given that conceptual understandings from lesson 1 are carried as prior knowledge into lesson 2, etc. Lesson objectives and standards will vary per lesson.*

### **Lesson 1: Surface Area Nets**

**Concepts:** Students will understand two-dimensional representations of three-dimensional objects can be used to visualize and solve problems such as those involving surface area and volume.

**Standards:** (PREREQ) NCTM 3 3-5 #4  
2061 9C 3-5 #1, #4, #5

(MEETS) NCTM 3 6-8 #4.2, #4.4, #4.5  
2061 9C 6-8 #1

(ADDRESS) NCTM 3 9-12 #1.1, #1.2

**Objectives:** Students will make and label 2-dimensional geometric nets for rectangular solids/cubes using cardboard boxes and drawing paper.  
Students will make and label 3-dimensional solids using nets and visualization.  
Students will use the nets to determine surface area.

### **Lesson 2: Volume of Rectangular Prisms and Cubes**

**Concepts:** Students will understand that description, classification, and understanding of geometric models can be used to represent and explain numerical and algebraic relationships.  
Students will understand relationships among types of two- and three-dimensional objects using their defining properties.

**Standards:** (PREREQ) NCTM 3 3-5 #1, #4  
2061 9C 3-5 #1, #5

(MEETS) NCTM 3 6-8 #1.1, #4.2, #4.4, #4.5; NCTM 8 6-8 #1  
2061 9C 6-8 #1

(ADDRESS) NCTM 3 9-12 #1.1, #4.1  
2061 9C 9-12 #1

**Objectives:** Students will find surface area of cereal boxes using rulers and determine volume of cereal boxes using solid cubes.  
Students will communicate conceptual understanding of surface area & volume.

**Lesson 3:** Surface Area and Volume Formula

**Concepts:** Students will understand formula development strategies to determine the surface area and volume of prisms.  
Students will understand techniques and tools to accurately find length, area, and volume.

**Standards:** (PRERQ) NCTM 4 3-5 #2  
2061 9C 3-5 #1, #5, #6

(MEETS) NCTM 4 6-8 #2.2, #2.4; NCTM 8 6-8 #1, #4  
2061 9C 6-8 #1

(ADDRESS) NCTM 4 9-12 #1  
2061 9C 9-12 #1, #2

**Objectives:** Students will apply surface area formula and volume formula for cubes and rectangular solids using cardboard boxes as geometric models.  
Students will collaborate and precisely express their understanding with peers and teachers using the language of mathematics.

**Lesson 4:** Dimensional Change Effects on Surface Area and Volume

**Concepts:** Students will learn when linear dimensions of a rectangular solid change the volume and surface area change disproportionately.

**Standards:** (PREREQ) NCTM 3 3-5 #4; NCTM 4 3-5 #1, #2  
2061 9C 3-5 #1, #4, #5, #6

(MEETS) NCTM 3 6-8 #2.4, #4.3, #4.4; NCTM 8 6-8 #1 – 4  
2061 9C 6-8 #1, #3, #6

(ADDRESS) NCTM 3 9-12 #4.1, #4.2  
2061 9C 9-12 #1, #2, #3

**Objectives:** Students will arrange-to-fit specific 2-dimensional shapes within 12" and 8" graphed circles.  
Students will construct, and arrange-to-fit 3-dimensional paper solids within 1-Liter and 20-ounce plastic bottles.  
Students will identify how surface area and volume changed after a size reduction.  
Students will accurately record and report mathematical applications and findings.

## **LESSON 1: NASA CONNECT PSA VIDEO CHALLENGE**

### **Main Lesson Concept**

Two-dimensional representations of three-dimensional objects can be used to visualize and solve problems such as those involving surface area and volume.

### **Scientific Question**

How can orthographic maps (*nets*) be used to visualize and model properties of geometric figures?

### **Instructional Objectives**

Students will make and label 2- and 3-dimensional geometric nets for rectangular solids using cardboard boxes and drawing paper.

Students will use the nets to determine surface area.

### **National Standards**

#### **Prerequisite**

NCTM: 3 3-5 #4

2061: 9C 3-5 # 1, #4, #5

#### **Meets**

NCTM: 3 6-8 #4.2, #4.4, #4.5

2061: 9C 6-8 #1

#### **Addresses**

NCTM: 3 9-12 #1.1, #1.2

### **Misconception**

Volume & surface area change proportionally. Students often believe that if volume increases, surface area increases by the same amount. Conversely, that if surface area increases, volume increases by the same amount.

Displaying two cubes can show this. Each has a volume and surface area; however when the two cubes are placed together the volume remains constant while the surface area has decreased.

### **Prerequisite Concepts**

Area can be thought of as a collection of unit squares.

## **Major Concepts**

Some shapes have special properties. Shapes can match exactly or have the same shape in different sizes.

Visualization, spatial reasoning, and geometric modeling can solve problems.

## **Suggested Timeline**

One class session.

## **Materials and Equipment**

Each student *PSA Team* member (teams of 3-4) will need pre-drawn nets of rectangular prisms, boxes (envelope boxes, cereal boxes, etc.) of various shapes and sizes for each team, Math Journal for drawing and recording data.

Teacher will need chalk/white board, boxes for display and demonstration, scissors and tape, gift wrapped present/box, student survey.

## **Engage**

**Actually perform this task in front of the class. This real life application will develop the concept of nets and views and a working vocabulary of: front view, back view, side view, top view, bottom view, and net.**

## **Discuss**

Suppose we wanted to unwrap a covered package to see what was inside.

As

we unwrap it we are going to unfold the package and lay it out flat. First we are going to carefully take the wrapping paper off trying not to tear it. Then we are going to set it aside and talk just about the package inside right now.

## **Question**

When you look at *this part* (show front view) of the package what shape do you see? *Encourage participation.*

## **Answer**

Rectangle.

**Question**

What part of the package is that shape?

**Answer**

Front

**Teacher Action**

Draw that size of a rectangle on the board and label it “Front View.” Continue this with each face of the package until all faces are drawn and labeled on the board.

<b>Front View</b>	<b>Back View</b>	<b>Left Side</b>	<b>Right Side</b>	<b>Top View</b>	<b>Bottom View</b>
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**Teacher Action**

Cut the box so that it is completely unfolded and still connected.

**Explain**

Notice how the package should be completely unfolded and still connected.

The unfolded package is an example of a **net**.

**Teacher Action**

Distribute boxes, scissors, & tape.

**Instruction**

Cut your boxes apart into pieces like pictured on the board.

**Explain & Instruct**

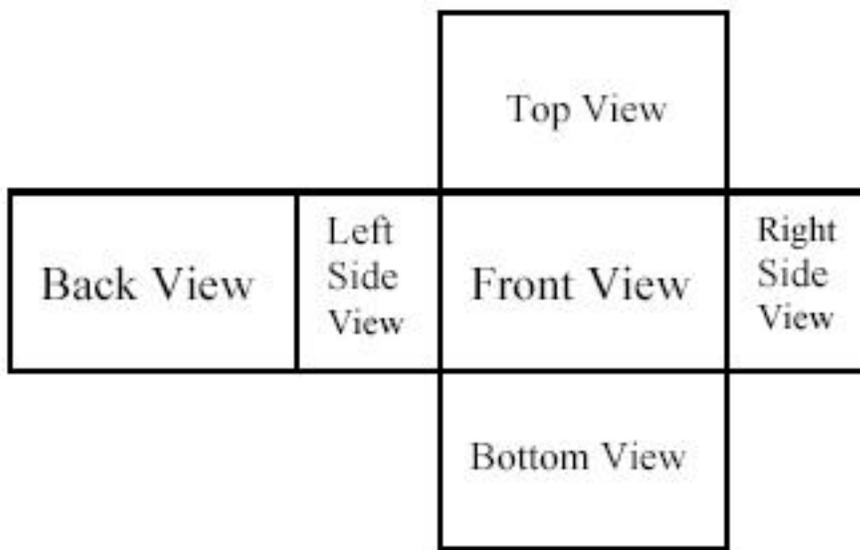
Now once you have all the pieces of a package it's like putting a puzzle together. When assembling the PSA NASA scientists and engineers had the same challenge.

Take the pieces and lay them on a table or desk edge-to-edge. As the pieces are put back together discuss the reason why a top view edge and a bottom view edge cannot be placed beside each other. *This package*

*is a prism, a 3-Dimensional shape, there are sides that fit in between the top and bottom faces.*

### **Teacher Action/Instruction**

Draw a 3-Dimensional rectangular prism on the board and talk students through how to draw unseen faces. Draw the views and label them. Demonstrate how to put the pieces into a **net** without cutting them. Emphasize visualizing it rather than cutting and pasting.



### **Explain**

There is more than one correct way to draw a **net** for a specific prism. We are going to experiment with some of those ways now. In order to complete the PSA NASA scientists and engineers had to consider varieties of solutions for the same problem.

Explore

Guided Activity

### **Teacher Action**

Distribute copies of pre-drawn rectangular prism **nets**.

Student Action

**Cut out, fold, and tape to form rectangular prism.**

**Cut out, cut into pieces, re-form net.**

**Teacher Action**

Distribute copies of cube nets.

**Student Action**

Cut out, fold, and tape to form the cube.

Cut out, cut into pieces, re-form net.

**Question**

What do you notice about the relationship between the two-dimensional (flat) nets and the 3-dimensional nets?

**Answer**

Each face of the 3-dimensional shape is one section of the net.

The location of a given face on the 3-dimensional shape is dependent on the location of a given section of the net. *Encourage discussion/questions.*

**Teacher Action/Instruction**

Teacher distributes cereal boxes, envelope boxes, etc. Have student teams

draw and label the views they see (front, back, top, bottom, left side, right side), and draw a net for their particular box.

**Student Action**

Draw and label the views of the box. Draw a net for the particular box.

Note to Teacher

Students may need to cut out the box faces and tape them back together.

**Teacher Action/Instruction**

Have student teams trade boxes and repeat drawing process of box views and nets using a differently shaped rectangular prism.

**Explain**

**Question**

What similarities and differences do you observe between the cube and a rectangular prism?

**Answer**

Cubes - all faces are the same size, Rectangular Prisms - faces are different sizes.

**Explain/Question**

NASA PSA scientists and engineers used models that represent the PSA. How might that be similar to what we've done?

**Answer**

We used boxes as geometric models to solve problems. Part of solving the problem for NASA (and for us) involved putting a model together like a puzzle. *Encourage discussion.*

**Note to teacher**

**More complex pre-drawn nets may be attempted depending on level of class and time permitted.**

**Teacher Action**

Draw another 3-D shape(s) on the board for students to observe.

**Student Action**

Students draw the views and net(s) of the shape(s) without cutting and pasting together.

**Teacher Action**

Elicit from student strategies they used for drawing views and nets without cutting and pasting.

## **Extend/Apply**

### **Constructed Response Performance Task**

#### **Teacher Action**

Display a cereal box and ask students to draw and label the views they see.

(Show front, back, top, bottom, left side, and right side).

#### **Student Action**

Draw the net of the box directly underneath the views they have just drawn. If they cannot visualize it, they may need to cut the pieces out and tape them

back together.

#### **Teacher Action**

Display differently shaped boxes. Instruct students to draw and label the net

for each individual box.

#### **Note to Teacher**

**Emphasize visualizing over cutting and pasting per NCTM Standards.**

#### **Teacher Action**

Encourage student discussion regarding visualization strategies for drawing

nets.

## **Evaluate**

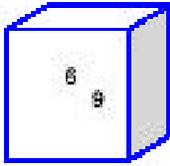
#### **Teacher Action**

Distribute student inventory.

#### **Student Action**

Demonstrate your understanding of nets and views by drawing the front

view, the side views, the top view, and the bottom view of the figure. Label them with the words front, top, bottom, and side. Also label the dimensions of each piece. If possible, draw these connected as a net.



Explain how the idea of nets views would be important to NASA scientists and engineers when they developed and built the PSA. Explain how the idea of visualization and geometric modeling would be important to them.

### **Teacher Action/Assessment**

Anecdotal observation of student understanding.

Review and provide assessment of student inventories & Math Journals using rubric criteria.

Addendum

#### **Student Inventory**

1. State how to determine the area of a rectangle.

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2. State in your own words what surface area is and what it means to you.

3. Find the area of a rectangle with the following dimensions: 5 cm x 7 cm.

4. Explain what the following mathematical terms mean.

**Nets-**

**Base Area-**

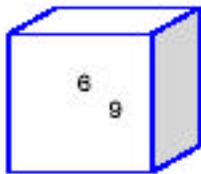
**Side Area-**

**Front View-**

**Side View-**

**Back View-**

Demonstrate your understanding of views by drawing the following: front view, side views, the top view, and the bottom view of the figure shown. Label them with the words front, top, bottom, and side. Label the dimensions of each piece. Draw these connected as a net.



Explain how the idea of nets and views would be important to NASA scientists and engineers when they built and developed the PSA.

Explain how the idea of visualization and geometric modeling would be important to them.

## **LESSON 2: NASA CONNECT PSA VIDEO CHALLENGE**

### **Main Lesson Concept**

Description, classification, and understanding of geometric models can be used to represent and explain numerical and algebraic relationships.

### **Scientific Question**

How can problems in surface area and volume be solved with geometric models?

### **Instructional Objectives**

Students will determine surface area and volume of rectangular solids using measurement and manipulatives. Students will communicate conceptual understanding of surface area and volume.

## **National Standards**

### **Prerequisite**

NCTM: 3 3-5 #1, #4

2061: 9C 3-5 # 1, #5

### **Meets**

NCTM: 3 6-8 #1.1, #4.2, #4.4, #4.5; NCTM 8 6-8 #1

2061: 9C 6-8 #1

### **Addresses**

NCTM: 3 9-12 #1.1, #4.1

2061: 9C 9-12 #1

### **Misconception**

Volume & surface area change proportionally. Students often believe that if volume increases, surface area increases by the same amount. Conversely, that if surface area increases, volume increases by the same amount.

Displaying two cubes can show this. Each has a volume and surface area; however when the two cubes are placed together the volume remains constant while the surface area has decreased.

### **Prerequisite Concepts**

Area can be thought of as a collection of unit squares. Volume can be thought of as a set of unit cubes. Formulas can be used to determine perimeter and area.

### **Major Concepts**

Relationships among types of two-and three-dimensional objects can be determined and expressed using their defining properties.

### **Suggested Timeline**

One class session.

### **Materials and Equipment**

Each student *PSA Team* (teams of 3-4) will need: Centimeter ruler, 2 (unopened) single-serving cereal boxes, 30 one-centimeter manipulative cubes, scissors, centimeter graph paper, Math Journal for recording estimates.

Teacher will need chalk/white board, single serving boxes for display and demonstration, scissors, and 300 one-centimeter cubes (sugar cubes can substitute).

## Engage

### **Discuss**

NASA scientists and engineers are pushing technology like never before with a new robot helper being used on the International Space Station

called

the Personal Satellite Assistant or PSA. The PSA has amazing computer technology cased inside its interestingly protective package. We can think about the PSA and NASA technology to help us understand the ideas of geometric surface area and volume.

### **Review**

The cereal, and other boxes we used in the previous lesson packaged and protected the various items that were inside them. Similarly, the PSA is not only a useful helper but also a package that holds and safely protects its contents.

***The sum of the area of all the views, or faces on the box is known as the surface area. It's labeled just as the area of a rectangle or square would be (units squared or square units). The amount of space that is inside the box is known as the volume. It can be determined by finding out how many three dimensional cubes will fit inside.***

### **Question**

How might surface area and volume be important to NASA scientists and engineers when they developed and built the PSA? *Encourage student discussion and elicit student responses.*

### **Answer**

NASA would need to be able to determine how much space was available for the contents of the PSA and how to package it most effectively.

NASA scientists and engineers would want to know how big or small the PSA was going to be. NASA would need to know how much they could spend on supplies and materials.

### **Teacher Action**

Distribute single serving cereal boxes.

## **Question**

Why are packages the size and shape they are? *Encourage student discussion and elicit student responses.*

## **Answer**

Various contents have different needs for protection and storage. Some shapes have special properties. Shapes can match exactly or have the same shape in different sizes.

## **Explain**

NASA scientists and engineers had to consider these ideas when designing  
and building the PSA.

Explore

Guided Activity

## **Teacher Action**

Distribute scissors, centimeter graph paper, centimeter ruler.

Student Action

**Cut out cereal boxes so they form one template (connected pattern) for the box when flattened out.**

## **Question**

How is the two-dimensional flat shape you have now like a net?  
*Elicit student responses.*

## **Answer**

The shape *is* a net without labeled views. It can be folded up into a rectangular prism.

## **Instruct**

Trace the pattern onto the centimeter graph paper and label each view, or *face* on the graph paper to show front, back, left, right, top, and bottom sides.

**Student Action**

Place cut out box onto graph paper, trace, and label each face on the graph paper with front, back, left, right, top and bottom sides.

**Instruct**

To the nearest whole centimeter make and record dimension (*length, width*) estimates of each face and share your estimates within your team. *Allow for few minutes of team estimation & discussion.*

**Teacher Action**

Elicit student estimates from each group.

**Instruction**

Have students measure and record the *length* and *width* of each face to the nearest whole centimeter on the centimeter graph paper.

**Student Action**

Use a centimeter ruler to measure and record the *length* and *width* of each face on the graph paper.

**Question**

What can we determine if we know the dimension measurements of *length* and *width*.

**Answer**

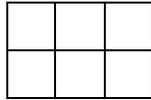
Area and perimeter.

**Instruction**

Have students find the area of each face by multiplying the length times the

width. (*Students may need to be reminded that (Area = length x width)*)  
Have students sum and record in Math Journals the areas of all six faces to determine the total surface area.

## Explain



Area is measured in square units, or units squared because it shows the measurement of two-dimensional, or flat surface dimensions of length and width.

## Student Action

Multiply the recorded length and width of each face to determine the area of each face. Sum the areas of all six faces to determine the total surface area of the rectangular cereal box.

## Explain

Surface area is measured in square units, or units squared because it shows the sum total measurements of two-dimensional, or flat surface dimensions of length and width that covers an object. Surface area is very useful. Here

are a couple of examples:

### **Examples**

*If had to paint my room I'd want to know how much paint I'd need to cover the walls – if I knew the surface area of the room I would know how much paint to buy.*

*If I was going to wrap a birthday gift box in special paper I'd want to know how much paper I'd need to cover the outsides of the box – knowing the surface area (sum total of all the areas of all of the sides) would tell me how much wrapping paper I'd need.*

### **Teacher Action**

Have students discuss the following question within their team.  
Have students report out their responses and justify them with evidence.  
*Allow several minutes for discussion & reporting.*

### **Question**

Why would NASA scientists and engineers want to understand the idea of surface area regarding the design and assembly of the PSA?

### **Answer**

NASA scientists and engineers need to understand surface area to know how much red paint to use, the amount of needed material for coverage, etc...

### **Teacher Action**

Elicit student responses and encourage discussion. *(Remember that the big idea behind surface area is covering, wrapping, or packaging something).*

Distribute a second set of single serving cereal boxes, and approximately 30 one-centimeter cubes for determining volume.

### **Instruct & Demonstrate**

Cut open one of the large faces on the box along three of its edges and remove the inner bag of cereal. Estimate and record the number of one centimeter cubes that will fit inside the box. Fill the single serving cereal box with one-centimeter cubes.

### **Student Action**

Cut open one of the large faces on the box along three edges and remove the inner cereal bag.  
Estimate how many one-centimeter cubes will fit inside the box. Record your estimates.

Fill the single serving cereal box with one-centimeter cubes.

**Note to Teacher**

**Some students may notice patterns in the layering of the cubes and will not need to fill the whole box. If cubes are unavailable sugar cube work well.**

**Explain**

**Question & Discussion**

What similarities and differences do you observe thus far between surface area and volume? *Elicit student responses.*

**Answer**

Surface area and volume show measurement of two- and three-dimensional shapes respectively. Surface area is like covering something. Volume is like holding something.

**Teacher Action**

Elicit student response and encourage discussion.

**Question**

How many cubes does the cereal box hold?

**Answer**

Most single-serving cereal boxes measure about 10 cm x 7 cm x 4 cm

**Question**

What does the number of cubes that the box can hold tell us?

**Answer**

The volume, or amount of “holding space” available in the cereal box.

**Explain**

Volume is very useful. Here is an example:

*If I was going to send boxes of movies and video games to my students I'd*

*want to know how much volume or available space was in the boxes to know*

*how many movies and video games I could fit in each box.*

### **Question**

Why would NASA scientists and engineers want to understand the idea of volume regarding the design and assembly of the PSA (a spherical, ball-like

shape being packaged with cube or rectangular shapes)?

### **Answer**

NASA scientists and engineers want to understand the idea of volume since

they had to determine how much space was available for supplies and materials, how large or small the PSA would be, etc...

### **Teacher Action**

Elicit student responses and encourage discussion. (*Remember that the big*

*idea behind volume is holding something).*

### **Extend/Apply**

#### ***Constructed Response Performance Task***

### **Explain**

We learned that when we find the area of *each* of the six faces (front, back,

left, right, top, bottom) on the rectangular prism (single serving cereal box), and then we sum the areas of all six faces of the rectangular prism (single serving cereal box) we can determine the total surface area.

### **Question**

What is surface area? How do we measure it?

### **Answer**

The area of all the faces of an object. It is measured by finding the area of

each face, then summing the areas of all six faces.

### **Teacher Action**

For the following questions elicit student responses and encourage discussion.

### **Student Action**

Students record solutions in Math Journals.

### **Note to Teacher**

**Questions facilitate understanding for determining volume formula.**

### **Question**

How many cubes are in each *layer* within the box?

How many cubes are in each *row*?

How many *columns* of cubes fit inside the box?

#### **Explain**

The number of cubes in each layer tells us height ( $H$ ) in centimeters.

The number of cubes in each row tells us width ( $W$ ) in centimeters.

The number of columns of cubes tells us length ( $L$ ) in centimeters.

*These are the measurements we use to determine volume.*

When we put those measurements into the formula  $V = L \times W \times H$  we are able to know the volume of our single-serving cereal box.

### **Teacher Action**

Encourage students to apply this formula using the information they just recorded and discuss within their teams.

### **Student Action**

Discuss results of the volume of their single serving cereal boxes.

### **Evaluate**

#### **Explain**

In your math journals use pictures, numbers, and words to describe and explain:

The concepts of surface area and volume.

How surface area and volume can be determined.

How and where surface area and volume are be useful in *daily life*.

How understanding surface area and volume is important to NASA scientists and engineers who designed and built the PSA.

**Student Action**

Respond in Math Journals then discuss responses within their teams.  
*Allow time for students to write, discuss and elaborate ideas regarding surface area, volume, and NASA PSA applications.*

**Teacher Action/Assessment**

Teacher anecdotal observation of student discussions. Review and provide assessment of Math Journals using rubric criteria.

**Student Action**

Each Team collaborates and prepares a brief summary statement that evidences their mathematical understanding of surface area, volume and its implications for NASA PSA.

**Teacher Action/Assessment**

Teacher anecdotal observation and rubric evaluation of team summary statements.

## **LESSON 3: NASA CONNECT PSA VIDEO CHALLENGE**

### **Main Lesson Concept**

Precise formulas, strategies, and techniques can be used with geometric tools to accurately determine surface area and volume of prisms.

### **Scientific Question**

How can mathematical formulas be used to understand the relationship between volume and surface area?

### **Instructional Objectives**

Students will determine the surface area and volume of rectangular prisms using mathematical formulas.

Students will collaborate and definitively express their understanding with peers and teachers using the language of mathematics.

### **National Standards**

#### **Prerequisite**

NCTM: 4 3-5 #2

2061: 9C 3-5 #1, #5, #6

#### **Meets**

NCTM: 4 6-8 #2.2, #2.4; NCTM: 8 6-8 #1, #4

2061: 9C 6-8 #1

#### **Addresses**

NCTM: 4 9-12 #1

2061: 9C 9-12 #1, #2

### **Misconception**

Volume & surface area change proportionally. Students often believe that if volume increases, surface area increases by the same amount. Conversely, that if surface area increases, volume increases by the same amount.

Displaying two cubes can show this. Each has a volume and surface area; however when the two cubes are placed together the volume remains constant while the surface area has decreased.

## **Prerequisite Concepts**

Area can be thought of as a collection of unit squares. Volume can be thought of as a set of unit cubes. Formulas can be used to determine perimeter and area. Areas of irregular shapes can be found by dividing them into squares and triangles.

## **Major Concepts**

Some shapes have special properties. Shapes can match exactly or have the same shape in different sizes.

Organized mathematical language is used to clearly communicate precise mathematical ideas to others.

## **Suggested Timeline**

One class session.

## **Materials and Equipment**

Students teams of 3-4 will need 2-3 small standardized rectangular boxes (*single serve cereal boxes*) scissors, tape, drawing paper, graph paper, metric rulers, and Math Journals.

Teacher will need observational records journal.

## **Engage**

### **Discuss**

Within your lifetime it is highly probable that people will travel to Mars and possibly even establish human supported stations there!

So imagine yourself in your new career as a pioneering NASA scientists or engineer who will help make this happen. As we've seen math and science

understanding will be important to help achieve this exciting opportunity for exploration. Essential understanding of volume and surface area are important for scientists and engineers working on the PSA for the ISS - the ideas we've been looking at with surface area and volume will also be essential for us.

## **Review prior lesson 2**

Thinking back to our recent investigations let's talk about the surface area

and volume of a rectangular prism.

### **Instruction**

Explain to your team what we discovered about the surface area of rectangular prisms in the prior investigation.

### **Note to Teacher**

**Allow time for students to discuss, monitor dialogue - some students may need instructional prompting.**

### **Question/Discussion**

What can we say about the surface area of cubes and rectangular prisms?

### **Answer**

Surface area is about covering or wrapping something. When disassembled, rectangular prisms are made up of connected views, or faces.

The faces can be assembled in a net (*orthographic map*) to show the 3 dimensional shape on a 2-dimensional plane. The net can be reassembled into a 3-dimensional shape.

We can determine surface area by summing all the areas of all the faces. Surface area is labeled in square units.

### **Question**

How would surface area be important to NASA scientists and engineers working on the PSA?

### **Answer**

NASA would need to know how much space they needed to cover or package, how large or small PSA was going to be, how much they could spend on supplies and materials, etc.

*Elicit student responses and encourage discussion.*

### **Question**

What relationships did we discover existed between cubes and rectangular prisms?

### **Answer**

Cubes - all faces are the same size. Rectangular prisms - all faces are different sizes. Nets can be used to understand surface area for cubes and rectangular prisms.

### **Question/Discussion**

What can we say about the volume of cubes and rectangular prisms?

### **Answer**

Volume is about holding something in a space.

Volume is about 3-dimensional measurements.

Using the number of cubes that fit into each *layer*, *row*, and *column* inside the cereal box we were able to determine the volume of the box.

The number of cubes in each *layer* tells us the *height* of the box.

The number of cubes in each *row* tells us the *width* of the box.

The number of cubes in each *column* tells us the *length* of the box.

Multiplying the *height* times the *width* times and *length* tells us the volume of the box.

### **Question**

How would volume be important to NASA scientists and engineers working on the PSA?

### **Answer**

NASA would need to know how much space was available for PSA components and materials, etc. *Elicit student responses and encourage discussion.*

### **Explain**

We know that in math we can determine important ideas by using formulas (*an equation that states a rule or fact*).

For example we know that in order to determine area of a quadrilateral we can say: *Area = length x width*

### **Question**

How else can we usefully use this formula?

**Answer**

To determine surface area of a cube or rectangular prism - when all areas are known they can be summed to determine the total surface area.

**Explain/Question**

Just like the formula  $A = \text{length} \times \text{width}$  tells us the area in square units for quadrilaterals what else can we use formulas for?

**Answer**

To determine other shape measurements.

Explore**Explain**

In the previous investigations we used nets to show surface area by enclosing and measuring a space. We used boxes and cubes to show volume by filling and measuring a space.

**Question**

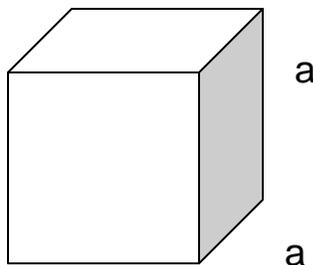
What is the surface area of a cube?

**Answer**

The surface area of a cube is the area of the six squares that cover it.

**Explain**

The area of one of the squares is  $(a \times a)$  or  $(a^2)$ . (*"a" is the length of the side of each edge of the cube*).



### Explain

Since these areas are all the same, you can multiply one of them by six. So the surface area of a cube is 6 times one of the sides squared.

### Surface Area of a Cube = $6a^2$

We say squared since the exponent in the formula indicates repeated multiplication. (*a times a, or a times itself*)

### Explain

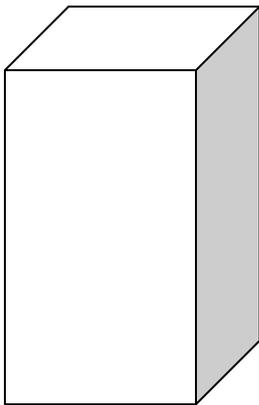
We use the number 2 for the exponent in the formula since we are multiplying two dimensions thus finding an area.

Area is expressed in units squared since it is the number of square units that cover a given shape or figure.

Rectangular S. Area =  $2ab + 2bc + 2ac$

(a, b, c are the lengths of the 3 sides)

So, the surface area of a rectangular prism is the area of the six rectangles that cover it. But we don't have to figure out all six because we know that the top and bottom are the same, the front and back are the same, and the left and right sides are the same.



The area of the top and bottom (side lengths a and c) =  $a \cdot c$ . Since there are two of them, you get  $2ac$ .

The front and back have side lengths of b and c. The area of one of them is  $b \cdot c$ , and there are two of them, so the surface area of those two is  $2bc$ .

### Explain

The left and right side have side lengths of a and b, so the surface area of one of them is  $a \cdot b$ .

There are two of them, so their combined surface area is  $2ab$ .

**Rectangular Surface Area =  $2ab + 2bc + 2ac$**

**Question**

What is the volume of a rectangular prism?

**Answer**

The volume of a rectangular prism is the measurement of available space inside the prism.

**Explain**

Volume of a rectangular prism =  $a \cdot b \cdot c$  units cubed.

*(length 'a' x width 'b' x height 'c')*

Area is measured in "cubic" units. The volume of a figure is the number of cubes required to fill it completely, like cubes in a box.

We say cubed since the exponent in the indicated repeated multiplication.

*(length x width x height)*

We use the number 3 for the exponent in the formula since we are multiplying three dimensions thus finding a volume.

Volume is expressed in units cubed since it is the number of cubic units that fill a given shape or space *(like cubes in a box)*.

**Teacher Action**

To each student team member distribute small rectangular boxes,  
scissors,  
drawing paper and metric rulers to students.

**Instruction**

Students will remove the tape or other material holding the rectangular box together and spread out the parts onto the drawing paper on a flat surface and sketch or trace the net of the rectangular box.

**Student Action**

Fold out or cut out the box into a flat shape and sketch or trace the net of  
the  
box.

**Instruction**

Have students measure the length of each side of each face of the open  
box  
and record results in Math Journals.

**Student Action**

Students measure and record each face of the open box.

**Instruction**

Have students measure one of the ends of the box and record results in Math Journals.

**Student Action**

Students measure and record one of the ends of the open box.

**Instruction**

Have students measure the front of the box and record results in Math Journals.

**Student Action**

Students measure the front of the box and record results in Math Journals.

Back view \_\_\_\_\_ cm. Left side view \_\_\_\_\_ cm.  
Top view \_\_\_\_\_ cm. Front view \_\_\_\_\_ cm.  
Bottom view \_\_\_\_\_ cm. Right side view \_\_\_\_\_ cm.

**Instruction**

Have students label the measurements on the box with a pen or marker.

**Question**

What have determined so far with our measurements?  
*Elicit student response & discussion.*

**Answer**

The 2-dimensional measurements of each face of the box.

**Question**

Are some of the measurements the same? If so, which ones?  
Elicit student response & encourage discussion.

**Answer**

Just as in the previous investigations the properties of a cube determine that it will have identical measurements on all its sides. Additionally, the properties of a rectangular prism determine that opposite faces will have identical measurements on opposite sides.

**Instruction/Question**

Within your team talk about and be prepared to report on and justify the following questions. Are there faces of the box that have exactly the same measurements? Does this apply to any rectangular prism?

**Note to Teacher**

**Allow time for student teams and whole group to adequately make and justify their positions.**

**Answer**

Yes, there are faces of the box that have exactly the same measurements – this does not apply to any rectangular prism. For example, a single serving cereal box has the same measurements on opposite faces, but not the same measurements on all faces. A cube shaped box has the same measurements on all faces. *Encourage discussion & connections to previous investigations.*

**Explain**

Work with your group to find the area of each section of the box, add them together and find the total surface area of the box.

Back view \_\_\_\_\_ cm. Left side view \_\_\_\_\_ cm.

Top view \_\_\_\_\_ cm. Front view \_\_\_\_\_ cm.

Bottom view \_\_\_\_\_ cm. Right side view \_\_\_\_\_ cm

Total surface area \_\_\_\_\_ sq. cm.

**Teacher Action**

Have students report the surface area they found and turn the box over for re-use with a second exploration.

**Explain**

We're going to re-use our rectangular prisms to investigate volume.

**Question**

What are some possibilities about why the idea of re-use or recycling is important to NASA astronauts on board the ISS, and to scientists

supporting them from Earth? *Elicit student response and facilitate discussion.*

### **Answer**

On the ISS there's a limited amount of space, supplies, and materials that have to last for long periods of time. Re-using or recycling allows supplies and materials to extend their use-time, which saves money, and time, etc...

### **Teacher Action**

Have students reassemble their rectangular prisms with tape.

### **Instruction**

In your math journal give an estimate of the volume of the small box. Use your previously collected surface area measurement data to determine the volume of the box. Record these results in your math journal.

### **Question**

What was the volume of your box?

### **Teacher Action**

Elicit student response and discussion.

## **Explain**

### **Question**

What does the number we found for total surface area tell us?

### **Answer**

The number we found tells us total surface area of the box – the total measurement of 2-dimensional space that can cover the of the surface.

### **Question**

What does the number for we found volume tell us?

**Answer**

The number we found tells us the volume of the box - the measurement of available space inside the box.

**Question**

Why do we use square units or units squared to express surface area measurements?

**Answer**

It shows the measurement of two-dimensional, or flat surface dimensions of length and width. It shows how many 1 x 1 unit squares are needed to cover or wrap an object.

**Questions**

Why do you use cubic units or units cubed to express volume measurements?

**Answer**

Volume is expressed in units cubed since it is the number of cubic units that fill a given shape or space (*like how many cubes fit in a box*).

**Answer**

It shows how many 1 x 1 x 1 unit cubes are needed to fill an object.

**Question**

What types of relationships exist between surface area and volume?

**Answer**

Since they use different measuring units it can be challenging to compare surface area and volume. (*It's like asking why I am sometimes older than my weight*). Volume looks at how much space, or capacity is inside of a 3-dimensional object. Surface area looks at the amount of enveloping 2-dimensional surface space on the outside of the 3-dimensional object.

## Question

How do surface area and volume affect one another?

## Answer

Surface area and volume change disproportionately – as one changes in size the other changes in size by a different factor. Surface area and volume change by different amounts.

**When Volume is constant, the maximum surface area occurs with the most elongated package and minimum surface area occurs with the most cube-like**

## ***Constructed Response Performance Task***

### **Explain/Instruct**

Discuss with your team the following three topics:

1. How NASA scientists working with the PSA Project might make effective use of surface area and volume when designing and building the PSA.
2. Discuss with your team when in the real world you might apply the concepts of surface area and volume. Explain why you'd chose to find volume and surface area as opposed to just finding area.
3. Imagine you are telling someone else how to figure surface area and volume what do you tell them? Practice this scenario with your team.

### **Explain**

Use your math journal to record all data to demonstrate your understanding of views and nets by creating an example of your own (*actually construct the 3-D figure with graph paper, scissors, and tape*)

### **Explain/Instruct**

Sketch the 3-D view of the rectangular prism OR the net of it, measure it's dimensions and label them on your sketch. In an organized manner, show all the steps to calculating the surface area and volume of the figure.

### **Student Action**

Collaborate within teams to logically discuss given topics.  
Complete the 3-D figure construction and measurement project.

**Teacher Action**

Facilitate student team discussions. Maintain observational records journal.

**Evaluate****Discussion**

Student team conversations/insights from topics (1, 2, and 3).  
Check for student understanding.

**Teacher Action**

Apply observational records journal anecdotes from student discussions  
on  
topics (1, 2, and 3) as assessment. Collect and review student  
constructed  
figures and math journals for use as assessment. Evaluate for accurate  
measurements and concept applications.



## Evaluative Rubric Criteria Guide

Scoring Levels	Level 6	Level 5	Level 4	Level 3	Level 2	Level 1
<b>Mastery of Topics</b>	Mastery of all topics	Mastery of almost all topics	Mastery of most of the topics	Mastery of several of the topics	Mastery of few of the topics	Limited understanding of only a few of the topics
<b>Solutions Explanation</b>	Clear, convincing explanation of all solutions	Clear, convincing explanations of most solutions	Clear, convincing explanations of many solutions	Clear, convincing explanations of several solutions	Clear, convincing explanations of a few solutions	Partial explanations of a few solutions
<b>Errors Committed</b>	Almost no errors	Few errors	Some errors, most of which are minor	Significant number of errors, some of which are major	Many, errors, including several major ones	Errors throughout the entire assessment, including many major ones
<b>Steps Shown</b>	All steps shown in each solution	All steps shown in most solutions	All steps shown in many solutions	All steps shown in several solutions; most steps shown in other solutions	All steps shown in a few solutions; some steps shown in other solutions	Some steps shown in some solutions
<b>Response to Open Questions</b>	Excellent, accurate responses to open-ended questions	Satisfactory and accurate responses to open-ended questions	Satisfactory responses to some of the open-ended questions	Satisfactory response to at least one open-ended question	An attempt to respond to at least one open ended question	Inappropriate responses, or no responses, to all open-ended questions
<b>Response to Problems</b>	Correct, complete responses to almost all of the more difficult problems and all basic problems	Correct, complete solution to many of the more difficult problems and all basic problems	Correct, complete solutions to several of the more difficult problems and all basic problems	Attempts solutions to some of the more difficult problems and correctly completes basic problems	Completes most basic problems correctly	Has difficulty completing any basic problems correctly

## References and Resources

*NASA Intelligent Systems Project*

*NASA Computing, Information, and Technology Program*

*NASA Engineering Complex Systems (ECS)*

### **NASA Cross Enterprise Technology Development Program**

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