**Asteroid Mining PBL**

**Grade Level:** 9 **Subject:** Coordinated Science

**Authors:**

Amy Colburn (Everett High School), Natascha Cox (Jackson High School),   
Scott McComb (Raisbeck Aviation High School) Steve Haynack (Marysville Getchell High School), David Hahs (Boeing), Mario Lotmore (Boeing), Eric Lagally (Western Governors University)

**Problem Statement:**

Our human population is growing faster than ever. With almost 8 billion people on the planet, we need massive amounts of resources to meet everyone's needs. Resources on Earth are not infinite; eventually, we will run out. Mining of those resources is often costly, hazardous to human life, and devastating to the environment. We need a better solution.

Mining asteroids is one solution. Scientists have discovered that asteroids contain many of the resources that we need and could be mined without harming Earth. While asteroid mining may seem like an outlandish suggestion at first, some companies have already started to seriously explore the possibility of mining asteroids, including some in the Puget Sound region.

In this project, you will investigate the challenges, decisions, risks, and rewards faced by these companies.

**Conceptual Storyline:**

During this unit students will design, construct and test a model asteroid ore processor using the steps of the engineering design process as outlined below:

1. Research: the unit employs a “jigsaw” team approach, in which student groups consist of students who each become experts in different aspects of the problem and possible solutions. These experts groups are Asteroid Composition, Prospecting, and Harvester Design. The first phase of the project involves the expert groups meeting together to learn the background about their expertise area and then reporting back to their team with the information they have learned.
2. Planning: Given the constraints identified by the experts in their groups and by the unit itself (total allowable budget), the students choose (1) a prospecting method, (2) a particular asteroid (out of 20 total) that they plan to mine, (3) the target material that they will mine from that asteroid, and (4) how much raw material they will pay to harvest. Each choice involves cost/benefit analysis and the calculation of the probabilities of successfully mining various materials.
3. Design Processor: Following the decisions in Step 2, students work together to design a processor for the particular material that they will mine. Various construction materials have associated costs, allowing students to make further cost/benefit decisions.
4. Build Processor: Students work together to construct the processor according to the design in Step 3.
5. Mine ore: Students test their processors by using the amount of raw ore they have paid to harvest. Students measure the total amount of desired purified product they successfully mine as well as the total amount of waste material generated, allowing calculations of purity.
6. Redesign: Given remaining time, students re-design their processors in an attempt to increase the yield of purified product as well as its purity.
7. Reporting out: Students generate communication about their final results at several points in the project, including a press release at the end of Step 2 and a final presentation following processing.

Prior to this unit students should have:

Experience working in groups for 21st century skills as well as processing and decision making within a group. Our suggestion would be to have other smaller PBL units beforehand so that students feel more comfortable with the process before beginning a 10-15 day unit.

In terms of content, students could complete the project as a stand alone unit. The basic concepts are covered within the asteroid mining PBL, but for more in-depth analysis and discussion, the following material could be covered beforehand:

* Asteroids - what are they and what do we know about them
* Spectroscopy and the electromagnetic spectrum
* Risk vs rewards
* What makes a good Press Release
* Budgeting

**Standards (NGSS, CCSS, CTE):**

CCSS Math Standards[[1]](#footnote-0):

CCSS.MATH.CONTENT.HSS.MD.B.5[[2]](#footnote-1).

Weigh the possible outcomes of a decision by assigning probabilities to payoff values and finding expected values.

CCSS.MATH.CONTENT.HSS.MD.B.7[[3]](#footnote-2).

Analyze decisions and strategies using probability concepts (e.g., product testing, medical testing, pulling a hockey goalie at the end of a game).

NGSS Science Standards:

HS-PS4-5

Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

HS-LS2-7

Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

HS-ESS3-2

Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

HS-ETS1-2

Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

**21st Century Skills:**

Collaboration, Creativity, Communication, Problem-Solving, Critical Thinking, Enthusiasm

**Locally and/or Personally Relevant for Students:**

Several companies in the Puget Sound region, including Planetary Resources, are currently developing plans and/or technology for harvesting and processing ore from asteroids. In addition, mining is a common activity across the region and the country, allowing instructors to leverage local mining activities and companies during the unit.

**Connections to career and educational pathways:**

* Working as a partner within a larger group helps enforce 21st century skills that are needed for any career or educational pathway
* Making decisions for various scenarios and justifying those choices using risk and reward is used in almost all fields of study
* The content is based on a globally relevant need and connects directly with possible careers in similar fields or with companies that are doing this research and eventual asteroid mining
* Can also help to get more students interested in STEM fields as a whole using any number of specific interests, including asteroid mining, mining in general, clean energy sources, engineering design, and environmental engineering.

**Table of Contents/Overview of Unit:**

1. Teacher Preparation and Materials
2. Lesson 01: Project Introduction
3. Lesson 02: Expert Groups
4. Lesson 03: Cost, Risk, & Reward
5. Lesson 04: Asteroid Mining Plan & Advertisement
6. Lesson 05: Processor Initial Design
7. Lesson 06: Processor Initial Build
8. Lesson 07: Finish Initial Build & Test/Refine
9. Lesson 08: Harvest & Analysis of Design
10. Lesson 09: Reflection & Analysis
11. Lesson 10: Elevator Pitch

**Teacher Preparation and Materials**

**Materials needed for the unit:**

Materials are provided for this unit in two different formats. In the first format, the assignments and student materials are provided digitally and collected the same way using Google Drive or a school-hosted LMS. The second method assumes no such technology and student materials are provided as handouts and packets. Both formats require the following materials:

* **Student and Presentation Materials:** the following is a list of all handouts and presentations. 00 Asteroid Mining Student Packet is a compilation of all group handouts. Each group could get a packet at the beginning of the PBL to avoid passing out papers during each lesson.
  + 00 Asteroid Mining Student Packet (the items with an \* are included in this packet)
  + 00 Guiding questions
  + 01 Asteroid mining
  + 01a Project introduction\*
  + 01b Team operating agreement\*
  + 02a Paying (and getting paid) for asteroid mining\*
  + 02b Information for asteroid functional group
  + 02c Information for prospecting functional group
  + 02d Information for harvesting and processing functional group
  + 03a Summary of research\*
  + 03b Budget template\*
  + 03c Asteroid mining plan\*
  + 03d Asteroid composition grid
  + 03dx Asteroid composition grid example
  + 03e Asteroid harvesting grid
  + 03ex Asteroid harvesting grid example
  + 03f Asteroid gross return summary
  + 03fx Asteroid gross return example
  + 03g Asteroid map
  + 04 Advertising guidelines & template\*
  + 05 Initial processor design\*
  + 08 Initial design analysis\*
  + 08a Final design and analysis\* (this document is not referenced in any lesson plans but could be used for groups who finish early and want to redesign their processor based on their results and harvest again)
  + 09a Asteroid mining final analysis\*
  + 09b Elevator speech instructions\*
  + 09c Individual reflection

* **Guiding Questions:** These can be distributed to students as questions to prompt discussion among the teams or for instructors to use to guide group or team discussion. This document can be found under Student sheet *00 Guiding Questions*
* **Processor building materials:** A variety of items including tape, paper, cardboard, magnets, string, wooden dowels or skewers that the students may use to build their processors. See the student handout for a more detailed list of building materials.
* **Simulated asteroid materials:** These include:
  + 2000 small rubber bands (to simulate iron)
  + 120 paper clips (to simulate cobalt)
  + 250 pieces of dry macaroni (to simulate nickel)
  + 100 packing peanuts (divided into fourths, to simulate water)
  + 21 BBs or small ball bearings (to simulate platinum)
  + shredded paper (to simulate asteroid matrix)
  + Should also have extra materials on hand for sample asteroids
* **Asteroid clear plastic containers:** Also required are 28 Tupperware or similar containers with a volume of at least a quart to hold each of the different asteroid simulant combinations that students may choose to mine. 20 of the containers are for the actual asteroids and 8 are for sample asteroids students will use during the planning process. Additional containers are helpful to contain the “waste” material during processing. It is suggested that you have 20 additional waste containers, one for each asteroid to avoid confusion and make it easier to reuse materials between classes
* **Harvester Cups:** 4-6 sets of measuring cups for harvesters. Sets should include a ¼ cup, ½ cup, and a full cup. Students will use these during several phases of the project.

**Lesson 01: Project Introduction**

**Problem Statement Focus:**

What is the scope of the project? What tools will we have available to address the challenge? What are the intermediate milestones?

**Learning Objectives:**

Students will be able to provide the rationale for asteroid mining, outline the scope of the project, and establish a team operating agreement.

**Materials:**

Per group for introductory activity:

* one set of utensils for simulated mining; each group member should have a unique tool, e.g., one clothespins, one skewer or chopstick, one Kraft stick, one small spoon (sampler size at ice cream stores or delis), etc.
* one bin of a particular type of simulated ore, e.g., one group might have pretzels or pretzel sticks, another might have jelly beans, a third might have goldfish crackers, a fourth might have cheese ball snacks, etc.
* One bowl or cup for each group member to store simulated ore

Project introduction:

* Access to Presentation: *01 Asteroid Mining*
* Student Sheet: *01a Project introduction* (digital or paper copies for each student)
* Student Sheet: *01b Team Operating Agreement* (digital or paper copy for each group)

**Lesson Preparation:**

Prepare mining utensils for quick distribution (6-qt plastic bin or Ziploc bags work well)

Prepare samples of simulated ore: 6-qt plastic bins work well

**Time Required:** 55 minutes

**Grouping of students for instruction:**

Groups of three students with one or two groups of four students if necessary

**Procedure:**

1. Establish project groups for students
   1. Some options include random selection, student choice, teacher assigned, etc.
2. Hook: Explore the suitability of tools
   1. Provide the following instructions to students:

In a minute or two, you will be asked to acquire as many resources as possible using one of the utensils at your table. The youngest person at the table gets first pick, followed by the 2nd youngest, etc.

Once everyone has selected a utensil, send the oldest person at your table to pick a plate of materials.

At the signal, collect as many resources as you can in 60 seconds

* + 1. only your utensil may touch the materials or the plate
    2. one of your hands must be behind your back or under your leg during the entire resource collection period
  1. After students have harvested materials, instruct them to compare their results with their table mates, and to propose an explanation for differences in the amount of resources collected.
  2. Facilitate a class discussion with the entire class. Some questions to consider include:
     1. How does this activity relate to actual mining?
     2. Did the people at your table cooperate or compete? Why?

1. Introduce rationale for project by sharing the Asteroid Mining presentation. (Presentation: *01 Asteroid Mining*)
2. Review project introduction. (Student Sheet: *01a Project introduction*)
3. Generate team operating agreement. (Student Sheet: *01b Team operating agreement*)

If your students have access to computers, provide the following instructions:

* 1. Have one person in your group create a new folder on Google Drive.
     1. Naming conventions: <period> Asteroid Mining (<last name, last name, last name>)
     2. Example: If Sam Pull, Mike B. Lief, and Jen Urich work together in 3rd period, they would name their folder 03 Asteroid Mining (Pull, Lief, Urich)
  2. Give editing privileges to your teammates and your instructor
  3. Save a copy of *01b Team Operating Agreement* to your folder
     1. naming conventions: 00 team operating agreement
  4. Discuss and come to consensus on key points

If your students are working with hard copies

* 1. Distribute copies of the team operating agreement.
  2. Instruct students to discuss and come to consensus on key points
  3. Collect and file team operating agreements

1. Summarize and close the lesson.
   1. Ask students to consider the following questions, first as individuals, then with a partner: What strengths do you bring to your team? Have you ever considered where the raw material for the things around you come from? What happens after the easily-reached materials are mined out?
   2. Set the stage for tomorrow’s work, when students will be working in functional groups: some students will explore prospecting methods, others will research asteroid types, and others will investigate effectiveness of different harvesting and processing techniques.

**Accommodations**:

Pair students who have difficulties with reading or writing with students who do not.

**Extensions:**

Have students research and report on existing efforts to mine asteroids. Encourage students to find actual press releases announcing those efforts.

**Lesson 02: Expert Groups**

**Problem Statement Focus:**

What are key facts regarding asteroids, prospecting methods, harvesting methods, and processing methods? How are those facts represented in our model?

**Learning Objectives:**

Students will be able to gather key facts regarding asteroids, prospecting methods, and harvesting and processing methods.

**Materials:**

For all students

* Student Sheet: *02a Paying (and getting paid) for asteroid mining*

One copy per pair or group of students (~1/3 of each class will be in each functional group)

* Student Sheet: *02b Information for asteroid functional group*
* Student Sheet: *02c Information for prospecting functional group*
* Student Sheet: *02d Information for harvesting and processing functional group*

~8 sample asteroids

**Lesson Preparation:**

Prepare sample asteroids:

* Eight (8) 6-quart bins, approximately ½ full of shredded paper, ~50 rubber bands, ~15 pieces of foam, ~20 paper clips, ~3 BBs, ~25 macaroni (these are samples; precise quantities are not particularly important)

**Time Required:** 55 minutes

**Grouping of students for instruction:**

Members from yesterday’s teams separate to ensure representation in each of three functional groups: A: asteroid types; B: prospecting methods; C: harvesting & processing methods. If there are groups of 4, have two groups members go to the same functional group.

**Procedure:**

1. Introduce the day’s lesson: review yesterday’s work, connect today’s work to rest of project.
2. Instruct teams to select representatives to each of three functional group
   1. One team member will specialize in asteroid types, another will specialize in prospecting, and a third will specialize in harvesting / processing.
   2. Each specialist will be responsible for providing information to their team to help the team make decisions about rewards and risks associated with asteroid type, prospecting methods, and harvesting and processing methods. Specialists will be responsible for taking complete and accurate notes as the printed information will not be available later. (teacher note: consider imposing a fine for groups who need to reference the information again). Key questions that specialists need to answer include the following:
      1. What are expected costs associated with each method?
      2. What are the rewards?
      3. What are the anticipated risks?
      4. How is our model like real life? How is it different?
3. Clarify questions and expectations.
4. Students separate into functional groups.
   1. Provide Asteroid Functional Group with Student Sheet: *02a Paying (and getting paid) for asteroid mining* and Student Sheet: *02b Information for asteroid functional group*
      1. If students are recording work digitally, have them save the results of their research in their Google Drive using the following naming convention: 02 asteroid type research (<last name>)
      2. If students are recording work on paper, have them include their notes in the team folder.
   2. Provide Prospecting Functional Group with
      1. Student Sheet: *02a Paying (and getting paid) for asteroid mining*
      2. Student Sheet: *02c Information for prospecting functional group*
      3. Sample asteroids
      4. Harvester cups to give them an idea of how much sample material they get with each choice.
         1. If students are recording work digitally, have them save the results of their research in their Google Drive using the following naming convention: 02 Prospecting (<last name>)
         2. If students are recording work on paper, have them include their notes in the team folder.
   3. Provide Harvesting & Processing Functional Group with
      1. Student Sheet: *02a Paying (and getting paid) for asteroid mining*
      2. Student Sheet: *02d Information for harvesting and processing expert group*
      3. Sample processor building materials
      4. Harvester cups
      5. Sample asteroids
         1. If students are recording work digitally, have them save the results of their research in their Google Drive using the following naming convention: 02 Prospecting (<last name>)
         2. If students are recording work on paper, have them include their notes in the team folder.
5. As part of large group discussion,
   1. Ask one or two representatives of each functional group to share their insights.
   2. Outline how this information will help with future work.

**Assessment:**

Check team folders for summary of research.

**Accommodations:**

Pair students at higher reading levels with students at lower reading levels.

**Lesson 03: Cost, Risk, & Reward**

**Problem Statement Focus:**

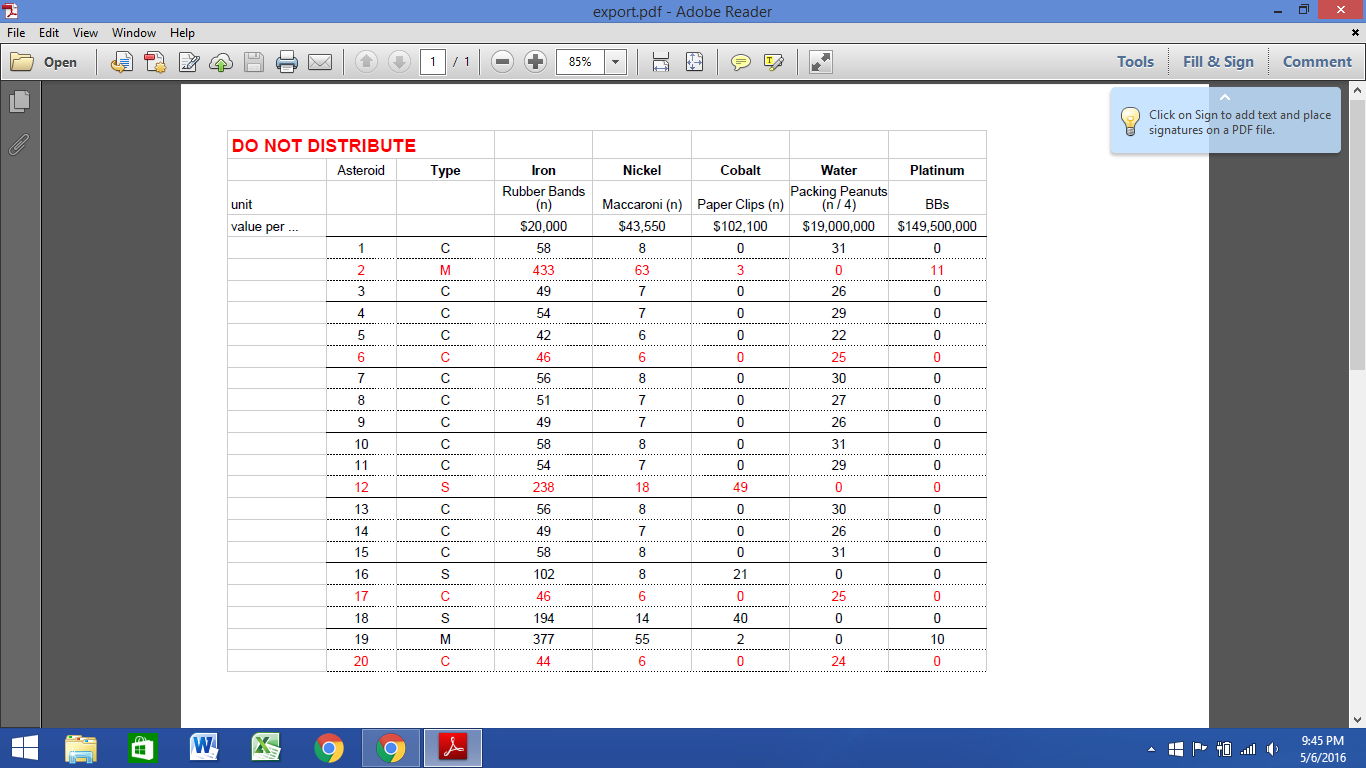
What are the costs, risks, and rewards associated with choices?

**Learning Objectives:**

Students will be able to outline cost, potential reward, and risks; and to make and justify choices

**Materials:**

20 asteroids according to the table below

  
Note: asteroids listed in red in image above are not included in the student-facing asteroid map *03g Asteroid Map*.

One copy for class:

* Student Sheet: *03g Asteroid map* (DO NOT DISTRIBUTE TO STUDENT GROUPS - see procedure section 6bi below for when to use)

One per team:

* Student Sheet: *03a Summary of research*
* Student Sheet: *03b Budget template*
* Student Sheet: *03c Asteroid Mining Plan*

**Only need the following items if the optional risk and reward exercise will be done:**

One per pair:

* Tissue or other material to clean transparency
* Colored pencils (5 colors)
* Overhead markers for each group (gray, red, green, orange, yellow, blue, black)
* Student sheet *03dx Asteroid composition grid example*
* Student sheet 03ex *Asteroid harvesting grid example*
* Student sheet *03fx Asteroid gross return example*

The following should be printed on transparencies for each student. More copies of the grids will be needed if students are going to complete extra practice.

* Student sheet *03d Asteroid composition grid*
* Student sheet *03e Asteroid harvesting grid*
* Student sheet *03f Asteroid gross return summary*

**Lesson Preparation:**

Make a 10x10 grid of painter’s tape on the floor or front board

Create the 20 asteroids

**Time Required:** 55 minutes (+30-45 minutes with optional risk and reward grid exercise)

**Grouping of students for instruction:**

Teams or, if conducting the risk and reward exercise, in partners

**Procedure:**

1. Introduce the day’s lesson and connect it to the larger project.
2. Instruct students to summarize their key findings from Lesson 02 and document that conversation using Student Sheet: *03a Summary of research*.
   1. If students are recording work digitally, have them save the results of their research in their Google Drive using the following naming convention: 03 Summary of Research
   2. If students are recording work on paper, have them include their notes in the team folder.
3. OPTIONAL but recommended (if including, will take approximately 30-45 minutes): Have students complete the risk and reward grid activity
   1. Hook
      1. Make a 10 x 10 grid of tape on the floor or front board where it is easily visible to all students in class.
      2. Challenge a student to throw a small disk (e.g., lid to container) so that it lands flat in a specific square. Consider offering an imaginary wager: offer to pay $100 if the student makes it, but require him / her to pay you $20 if s/he misses.
      3. Discuss strategies and rationale.
      4. Allow several students to try.
   2. Instructions
      1. Relate activity from hook to mining for ore on asteroids.
         1. Measurable chance of success
      2. Distribute sample asteroids with known composition. Ask, “What are the chances of getting specific types of ore if we chose a medium harvester (1/2 cup) and spectroscopy (two scoops)?” Ask, “What else do we need to know to make an informed decision?” [Anticipated response: total volume in bin. Answer: ~96 ounces]
      3. This next activity will model likelihood of success (and failure) = risk
      4. Distribute the following to each pair of students:
         1. Student Sheet: *03d Asteroid composition grid* and Example
         2. Student Sheet: *03e Asteroid harvesting grid* and Example
         3. Overhead markers
         4. Colored pencils
         5. Tissue
   3. Model
      1. Each square in the 8x12 grid represents one ounce of the asteroid material.
      2. Sample asteroid (M-type) has no foam (water), 80 rubber bands (iron), 1 bb (rare earth metals), 11 macaroni (nickel), 1 paperclip (cobalt), and shredded paper.
      3. Have each person work individually to create an asteroid with a random distribution of the ore. On the first grid on the asteroid composition grid, using overhead markers, have a student randomly fill in:
         1. 80 squares gray to represent iron
         2. 1 square red to represent rare earth metals
         3. 1 square green to represent cobalt
         4. 11 squares orange to represent nickel, and
         5. 3 squares yellow to represent asteroid matrix.
      4. Imagine a hypothetical group that decides to use medium-sized harvester (4 oz. each) and spectroscopy as its prospecting method (2 scoops). For the sake of this activity, that means that the team will harvest 4 oz x 2 times = 8 oz.
      5. Instruct each student to fill in 8 squares of their choice on their own ‘harvesting’ transparencies.
      6. Overlay the harvesting transparencies on the ‘asteroids’ created by partners. Ore is considered to be harvested if the square on the grid selected by one partner matches the square selected by the other.
      7. Evaluate the amount of ore ‘harvested’
   4. Discuss insights and have students complete Student Sheet *03f Asteroid gross return summary* (See 03fx example for reference)
   5. Guided Practice \*more copies of the transparent composition grids will be required to complete this practice
      1. Have each partner create another distribution, this time using typical amounts of ore from a C-type asteroid:
         1. 5 blue
         2. 10 black
         3. 80 yellow
         4. 0 green
         5. 1 orange
      2. Have each partner create another harvester grid, this time assuming a large harvester (8 oz) and a map (x3).
      3. Evaluate amount of ore harvested.
   6. Independent Practice \*more copies of the transparent composition grids will be required to complete this practice
      1. Have each partner create another asteroid grid (or two or three), modeling typical distributions in asteroid types they are interesting in mining
      2. Have each partner create another harvesting grid (or two or three), modeling harvester sizes and prospecting methods.
   7. Evaluate results
      1. Discuss insights as a class
4. Have teams discuss merits, costs, and risks associated with each prospecting and harvesting method.
5. Have teams decide on prospecting and harvesting method.
   1. If students are recording work digitally, have them save the results of their research in their Google Drive using the following naming convention: 03b Asteroid Mining Plan
   2. If students are recording work on paper, have them complete the prospecting and harvesting section on Student Sheet *03c Asteroid Mining Plan*, including risks and rewards for their choices.
6. Prospect and update financial statement
   1. Distribute Student Sheet: *03b Budget template*
      1. If students are working digitally, instruct them to save a copy into the team’s Asteroid Mining folder. Naming convention: 00 Budget
      2. If students are working with paper, instruct them to update their budget to reflect their choices for prospecting and harvesting
   2. Students complete prospecting method.
      1. Use Student Sheet *03g Asteroid map* for groups who prospect using the Map method
      2. Students record notes on prospecting
      3. Teacher tips:
         1. Only allow one person from each group to complete the prospecting. This helps keeps the number of people to a minimum
         2. Set-up 2 stations for prospecting. Tri-fold boards can be used to prevent groups from gathering information while other groups are prospecting
         3. Teacher can choose to put a time limit on prospecting
         4. If groups select the Asteroid map, our suggestion is to allow students to record patterns, trends, and some numbers but do not give enough time to copy down entire table from Asteroid map
7. To close, instruct students to summarize key insights in their teams. Ask a representative sample to share their insights with the class.

**Assessment:**

Ask a representative sample to share their insights with the class. (NOTE: a more formal and thorough assessment of student understanding is the focus of the next lesson in this sequence.)

**Extensions:**

See risk and reward exercise option in lesson plan. This will add another 30-45+ minute class period to the length of the PBL

**Lesson 04: Asteroid Mining Plan & Advertisement**

**Problem Statement Focus:**

Based on the prospecting results, what asteroid will be mined and what ore is the target? What are the risks and rewards associated with this choice? How can an advertisement be used to leverage the press and result in positive results for a company?

**Learning Objectives:**

Students will be able to outline cost, potential reward, and risks based on information gathered in a variety of ways. Students will be able to complete a press release summarizing their choices and reasoning.

**Materials:**

One per group:

* Student Sheet: *04 Advertising guidelines & template*

**Lesson Preparation:**

If students do not know what a press release is, have an example ready to show and discuss

**Time Required:** 55 minutes

**Grouping of students for instruction:**

Same teams as previous days

**Procedure:**

1. As a warm-up activity, teams begin with a recap of previous days accomplishments to catch up absent students and to make sure everyone is prepared to begin the day’s activities.
2. Introduce today’s lesson and connect it to the larger project
3. Have teams discuss the risks and rewards associated with choosing which asteroid and ore to mine based on expert groups and prospecting
   1. Students fill in remaining sections on *03c Asteroid Mining Plan*
4. Students complete company advertisement
   1. If students are recording work digitally, have them follow the guidelines from *04 Advertising guidelines & template* to create their advertisements.
   2. If students are recording work on paper, distribute Student Sheet: *04 Advertising guidelines & template*
      1. Students should use their Asteroid Mining Plan to complete all sections of the advertisement

**Assessment:**

Advertisement should be checked for completion. Probe each group's understanding of how they intend to see the project to completion. Teacher can address individual groups’ needs as appropriate.

**Accommodations:**

Provide additional scaffolding for ELL and students with special needs (e.g., sentence starters, etc.)

**Extensions:**

If students have access to computers, groups can make multimedia advertisements. Suggestions include a digital version with information that matches the template, powerpoint/prezi, or video.

**Lesson 05: Processor Initial Design**

**Problem Statement Focus:**

What features should a processor have to mine an asteroid for a specific type of ore? How much money should be spent on specific materials to build a processor?

**Learning Objectives:**

Students will be able to design a processor based on their asteroid mining choices and complete a budget to buy the materials to build said processor.

**Materials:**

Scratch paper for every student

One per group:

* Student Sheet: *05 Initial processor design*

**Lesson Preparation:**

Have building materials available for groups to purchase in case some groups get done with their initial designs quickly.

**Time Required:** 55 minutes

**Grouping of students for instruction:**

Same teams as previous days

**Procedure:**

1. As a warm-up activity, teams begin with a recap of previous days accomplishments to catch up absent students and to make sure everyone is prepared to begin the day’s activities.
2. Initial processor design brainstorming
   1. Students begin design process by individually drawing their personal idea on sheet of scratch paper
   2. Students share out one at a time. Other students in group are writing down one thing they like about each design and one thing they would change
3. Students complete the processor design and budget
   1. Teams decide on one design based on all ideas shared and complete Student Sheet *05 Initial processor design*
   2. Based on design, teams will need to use the table for material costs included in *02a Paying (and getting paid) for asteroid mining* and update the budget for items they would like to purchase
      1. Team budget sheets should now include prospecting choice, harvesting choice, and materials for first processor design.
      2. Teacher should check budget sheets and initial design before giving out materials
4. Time permitting, allow teams to purchase materials as they are ready and begin building

**Assessment:**

Check group progress through the design and budget paperwork.

**Accommodations:**

Teams will get to various stages at different paces as they go through the design and build process. Allow student groups to work through this process, but consider imposing deadlines and/or fines if groups do not get to certain checkpoints in a reasonable amount of time.

**Lesson 06: Processor Initial Build**

**Problem Statement Focus:**

How close to the design can we build the processor? What adjustments need to be made to make the processor work?

**Learning Objectives:**

Students will be able to build a processor that will sort material they want from material they do not want.

**Materials:**

Building materials ready for student teams to purchase.

**Lesson Preparation:**

Make sure enough building materials are available for all groups to meet their initial needs as well as additional unforeseen needs. Have harvestor cups and sample asteroids ready for groups that are ready to test early.

**Time Required:** 55 minutes

**Grouping of students for instruction:**

Same teams as previous days

**Procedure:**

1. As a warm-up activity, teams begin with a recap of previous days accomplishments to catch up absent students and to make sure everyone is prepared to begin the day’s activities.
2. As a reminder, discuss with students exactly what their processor should do. Outline restrictions, e.g., process for mining; credit for mining other non-targeted ore?
3. Assign mining auditors
   1. Students assigned to keep other groups accountable - allows teacher freedom to help other groups
4. Teams review/revise/finalize initial designs
   1. Teams get approval of initial design paperwork, and budget prior to purchasing supplies to build
5. Teams build processor
   1. Allow teams to take a sample asteroid and harvester cups to test designs if they would like. Charge teams according to *02a Paying (and getting paid) for asteroid mining* and have students update budget sheet.

**Assessment:**

Monitor teams during building process for collaboration and problem solving.

**Accommodations:**

Teams will get to various stages at different paces as they go through the build and test process. Allow student groups to work through this process, but consider imposing deadlines and/or fines if groups do not get to certain checkpoints in a reasonable amount of time.

**Lesson 07: Finish Initial Build & Test/Refine**

**Problem Statement Focus:**

How well does the processor sort the mined material? What improvements or adjustments need to be made?

**Learning Objectives:**

Students will be able to test the design of their processor and make necessary changes to maximize harvesting.

**Materials:**

* Sample asteroids available for testing
* Building materials ready for student teams to purchase
* Asteroids ready for harvesting
  + 20 asteroids prepared prior to prospecting
  + Extra bins to catch waste material while processing
* Harvester scoops
* Box or panel to put asteroids in while harvesting so students cannot see
  + We suggest a cardboard box with the sides removed - students can put hands in on either side to scoop, but cannot see

**Lesson Preparation:**

Make building materials available for teams to purchase. Have sample asteroids and harvestor cups available for testing.

**Time Required:** 55 minutes

**Grouping of students for instruction:**

Same teams as previous days

**Procedure:**

1. As a warm-up activity, teams begin with a recap of previous days accomplishments to catch up absent students and to make sure everyone is prepared to begin the day’s activities.
2. Teams finish building processors and test using sample asteroids. Charge teams according to *02a Paying (and getting paid) for asteroid mining* and have students update budget sheet.

Next class period agenda, but if some teams are ahead of schedule:

1. Teams harvest asteroids
   1. Do this in the presence of the mining auditor
   2. Processed material gets separated
      1. Record type and number of ore - add to budget as revenue
      2. Measure and record amount of waste - add to budget as waste removal fee
   3. Waste and processed material should all go back into bin when done
      1. NOTE: if more than one group is mining the same asteroid, return the waste immediately, but wait until the end of the period to return the ore

**Assessment:**

Monitor teams for collaboration and problem solving.

**Accommodations:**

Teams will get to various stages at different paces as they go through the test and refine process. Allow student groups to work through this process, but consider imposing deadlines and/or fines if groups do not get to certain checkpoints in a reasonable amount of time. All teams must mine by the end of the next lesson.

**Lesson 08: Harvest & Analysis of Design**

**Problem Statement Focus:**

How well does the processor hold the harvested material and sort the target material from the waste material? Was this design successful?

**Learning Objectives:**

Students will be able to process an asteroid, record processed ore and waste materials, and analyze their design.

**Materials:**

* One copy of Student Sheet: *08 Initial design analysis* per team
* Asteroids ready for harvesting
  + 20 asteroids prepared prior to prospecting
  + Extra bins to catch waste material while processing
* Harvester scoops
* Box or panel to put asteroids in while harvesting so students cannot see
  + We suggest a cardboard box with the sides removed - students can put hands in on either side to scoop, but cannot see

**Lesson Preparation:**

Have all asteroids available for harvesting. Keep them hidden from plain view but accessible to pull out for teams that are ready to mine. Depending on classroom set-up and materials, 2 to 3 teams could process at one time.

**Time Required:** 55 minutes

**Grouping of students for instruction:**

Same teams as previous days

**Procedure:**

1. As a warm-up activity, teams begin with a recap of previous days accomplishments to catch up absent students and to make sure everyone is prepared to begin the day’s activities.
2. Teams harvest asteroids
   1. Do this in the presence of the mining auditor
   2. Processed material gets separated
      1. Record type and number of ore - add to budget as revenue
      2. Measure and record amount of waste - add to budget as waste removal fee
   3. Waste and processed material should all go back into bin when done
      1. NOTE: if more than one group is mining the same asteroid, return the waste immediately, but wait until the end of the period to return the ore
3. Teams analyze initial design; fill out Student Sheet: *08 Initial Design Analysis*
4. Make sure processors remain intact for future gallery walk activity in lesson 10.

**Assessment:**

Observe use of teamwork while using processor and results of processing.

**Accommodations:**

All teams should finish mining by this lesson. Those that are behind must process even if they are not completely ready.

**Lesson 09: Reflection & Analysis**

**Problem Statement Focus:**

How successful was the mining plan? What could have been done differently? What was the overall profit/loss? What was the individual takeaway from the project? What information can we share in a short speech to interest an investor?

**Learning Objectives:**

Students will reflect on individual learning and mining plans success or failure and develop ideas that could make it better. Students will complete quantitative analysis of profit/loss. Students will create elevator pitch to promote investment.

**Materials:**

A copy for each team:

* *09a Asteroid mining final analysis*
* *09b Elevator speech instructions*

A copy for each student:

* *09c Individual reflection*.

**Lesson Preparation:**

Optional: A sample elevator pitch

**Time Required:** 55 minutes

**Grouping of students for instruction:**

Same teams as previous teams

**Procedure:**

1. As a warm-up activity, teams begin with a recap of previous days accomplishments to catch up absent students and to make sure everyone is prepared to begin the day’s activities.
2. Pass out student sheet *09c Individual reflection* and have students complete it on their own.
3. Pass out student sheet *09a Asteroid mining final analysis* and have groups complete.
4. Pass out student sheet *09b Elevator speech instructions* and give groups the remainder of the period to create speech.

**Assessment:**

Monitor student collaboration and time management. Pick up completed reflection and analysis forms and use as individual and/or team assessments.

**Accommodations:**

Teams may struggle to create elevator speech and can be given examples to reference.

**Extensions:**

Allow teams to film their responses.

Allow students a variety of choices of product.

**References/Resources:**

Elevator Speech <http://improvandy.com/elevator-pitch/examples-of-a-30-second-elevator-pitch/>

**Lesson 10: Elevator Pitch**

**Problem Statement Focus:**

What is the best way to promote asteroid mining?

**Learning Objectives:**

Students will present/evaluate elevator speeches and reflect on overall asteroid mining learning experience.

**Materials:**

Team processors, blank half sheets of paper

**Lesson Preparation:**

Clear area for students to give speeches. Cut enough full size paper into a half sheet for each students.

**Time Required:** 55 minutes

**Grouping of students for instruction:**

Same teams as previous days

**Procedure:**

1. As a warm-up activity, teams begin with a recap of previous days accomplishments to catch up absent students and to make sure everyone is prepared to begin the day’s activities.
2. Inform students of procedures for giving and listening to elevator speeches.
3. After speeches discuss best/most likely to attract investor.
4. Have students prepare for gallery walk by displaying processor and Asteroid Mining Final Analysis sheet.
   1. Students circulate room to view other designs and results
5. Once gallery walk is completed have class discussion of difficulties and learned skills.
6. Have individual students complete exit ticket on half sheet of paper finishing the following prompts about their asteroid mining experience
   1. I like..., I think..., I wish...

**Assessment:**

Use team speeches as group assessment and exit ticket as individual assessment.

**Accommodations:**

Speeches can be given as whole group where each student has a part or the group chooses one student to represent the group.

**Extensions:**

Use Kerbal or other rocket launch simulator to launch a rocket (with a harvester / processor payload) to the moon.

1. 2016 Common Core State Standards Initiative [↑](#footnote-ref-0)
2. http://www.corestandards.org/Math/Content/HSS/MD/B/5/ [↑](#footnote-ref-1)
3. http://www.corestandards.org/Math/Content/HSS/MD/B/7/ [↑](#footnote-ref-2)