Linking proportionality across the science and mathematics curricula through science literacy maps.(TEACHER'S TOOLKIT).

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Middle level science and mathematics teachers should collaborate to clarify concepts for students in each of these disciplines. The topic of proportionality is an excellent choice for a collaborative effort, as understanding proportionality is important in both science and mathematics.

The April 2003 focus issue of Mathematics Teaching in the Middle School touted proportionality as a unifying theme for the middle-grades mathematics curriculum. In Principles and Standards, the National Council of Teachers of Mathematics (2000) states: "The understanding of proportionality should also emerge through problem solving and reasoning, and it is important in connecting mathematical topics and in connecting mathematics and other domains such as science and art" (p. 211). The Atlas of Science Literacy from AAAS offers a set of science literacy maps for grades K-12 that can serve as a useful tool in helping teachers make connections between science and mathematics. Those who teach science and mathematics could especially benefit from the Atlas. The National Science Teachers Association (NSTA) promotes the inclusion of science and mathematics in all areas of scientific inquiry.

The idea of proportional reasoning is an excellent bridge into middle-grades scientific inquiry. Proportional reasoning is important in geometry, measurement, and probability and statistics, and science teachers depend on students being able to understand and manipulate proportions. The concept of density is one way to illustrate proportional reasoning in science (see Activity Worksheet for a student activity on density that can be used in both science and mathematics classrooms). Science and mathematics teachers can connect the disciplines in a way that will not only help their students but also inform their own teaching about the commonalities between mathematics and science.

The National Science Digital Library (NSDL) is an online resource consisting of science literacy maps and numerous juried resources for teaching science, technology, engineering, and mathematics (STEM) (see Resources). Science literacy maps are used to offer information about concepts and to help students construct their own understanding. They are also helpful to teachers as they provide a broad look at content and process skills across the science curriculum.

[ILLUSTRATION OMITTED]

Proportional reasoning and density

In science instruction, proportional reasoning is important because it allows students to construct the meaning of scientific concepts that are being illustrated. Mathematically, density is described as a ratio of the mass per unit of volume and subsequently can be computed to obtain a specific value for any substance. Scientifically, the density of a substance can be compared proportionally between water and other substances.

Water has a density of 1.0 gram of mass per 1.0 milliliter of volume. Substances that have a density greater than 1, or a mass that is larger than 1.0 gram per milliliter of volume, will sink when placed in water. Substances that have density that is less than one gram per milliliter will float. Additionally, proportional relationships using the same material with different masses and their associated volumes may be graphed to show proportionality in a linear graph.

FIGURE 1 Handout to accompany WebQuest

Density by graphical analysis

The purpose of this activity is to determine the composition of a mystery cylinder. As you complete the activities below, keep in mind the following questions:

1. What is the mystery cylinder made of?

2. Will it sink or float in water?

3. How can I use graphical analysis to help me determine the slope of the line?

4. How does the graph relate to density?

Introduction--Will it float or sink?

How do you know if something will float or sink? In this activity, you will graph your data of mass and volume to see if the mystery cylinder will sink or float. Your assignment is to determine the volume of an unknown object, the mystery cylinder, create a graph of your data, calculate the density of the cylinder, and finally, decide if it will float or sink.

Procedure

1. Find the volume of the mystery cylinder using the data table below. (Hint: Do you remember the formula for finding the volume of a cylinder? www.math.com/tables/geometry/volumes.htm.) Show your calculations.

Sample number	Mass (g)	Height (cm)	Diameter (cm)	Volume ([cm.sup.3])
1	2.49	3.69	1.10	
2	3.27	4.84	1.10	
3	4.83	7.16	1.10	
4	6.55	9.68	0.10	
5	8.73	12.95	1.10	

2. Now you are ready to graph your data so you can see the relationship between the mass and the volume of the cylinder.

3. Select the xy graph from the choices provided on the website given above. Put your volume on the x-axis and the mass on the y-axis. Be sure to define the parameters of your graph for the program (http://nces.ed.gov/nceskids/index.asp).

4. What relationship does the line show on the graph?

5. Find the slope of the line using your data. Show your calculations, and please use the first and last points for your data coordinates (www.wtamu.edu/academic/anns/mps/math/mathlab/beg_algebra/beg_alg_tut23_slope.htm).

6. What is the density of the cylinder based on the slope of the line?(www.edinformatics.com/math_science/density.htm).

7. Using the chart below, determine what your cylinder might be.

Substance	Density (g/[cm.sup.3])
Plastic	1.17
Steel alloy	7.81
Wood oak	0.710
Wax	0.948
Water	1.00

8. Will the substance sink or float in water?

9. Why do battleships float?

Evaluation

Check your work with the rubric!

Competency	4 points	3 points
Calculations	All were done correctly	Most were done correctly
Graph	Completed and printed out graph	Completed graph but no printout
Questions	Completed all questions correctly	Most were answered correctly

Competency	2 points	1 point
Calculations	A few were done correctly	None were done correctly
Graph	Incomplete graph	No graph
Questions	A few were answered correctly	No questions were answered

Several activities that teach and reinforce these concepts can be easily used in science and mathematics classrooms. An introductory WebQuest, Density by Graphical Analysis, introduces the concepts of density, graphing, slope, and ultimately the analysis of an unknown, by using calculated volumes (see Resources). Figure 1 is a handout to accompany the WebQuest. Once students have completed the WebQuest, they can conduct the laboratory-based activity where they use graphical analyses to determine the density of pennies minted before 1983 and after 1982. In 1983, more zinc was added to the copper alloy used to make pennies, therefore, the density of these pennies is closer to zinc than copper.

Science literacy maps: Atlas maps

The maps in the Atlas of Science Literacy are published by the American Association for the Advancement of Science (AAAS) and Project 2061. Volume 1 was published by AAAS and NSTA in 2001 to help educators achieve scientific literacy. Volume 2 was published in 2007. The Atlas of Science Literacy dovetails with the Benchmarks for Science Literacy (AAAS 1993), which let educators know what they should be teaching and students should be learning at different grade levels (grades 2, 5, 8, and 12) in order to be scientifically literate when they graduate from high school. Science for all Americans (Rutherford and Ahlgren1990) specifies the science that students should know and be able to do when they graduate from high school.

The maps provide teachers with an opportunity to align their instruction with state goals and national standards by offering access to a wide variety of lesson plans, activities, and professional articles. Many of the websites linked to the science literacy maps are interactive and offer students the opportunity to manipulate and test data.

Hassinger and Joiner (2007) have also provided information about the use of NSDL. The NSDL online library was established by the National Science Foundation (NSF) in 2000 to provide organized access to high-quality resources and tools that support innovations in teaching and learning at all levels of STEM education. Designed primarily for K-16 educators, anyone can access NSDL and search the library at no cost. Access to most of the resources is free; however, some content providers may require a login or a nominal fee to retrieve their specific resources. NSDL provides access to teachers and learners by supplying content and tools in open-access, nonproprietary formats in an easily accessible online environment. Resources include journal articles, teacher-created lesson plans, and realtime data sets from scientists. NSDL includes a K-12 portal and the maps are online and can be accessed using the Internet Explorer browser with a PC or the Firefox browser with a Mac. The map-knowledge and process-skills components are clickable and link users to resources that can be used to teach the knowledge and process skills indicated.

[FIGURE 2 OMITTED]

Figure 2 is an example of a complete map from the Atlas. In the paper copy the blue boxes on all of the strand maps represent knowledge that students should have, and the white boxes with blue borders represent skills that students should possess. On the website, all boxes are blue and clickable. The maps are designed to reflect the fact that mathematics is an integral part of scientific inquiry. Although NCTM's principles and standards terminology and structure are organized differently, NSDL offers a view of the mathematics curriculum through a scientific lens. Each map includes an overview of the scope and sequence of knowledge and process skills that should be learned in the early and upper elementary grades and middle and high school.

Teacher feedback

We conducted an afternoon inservice on use of the NSDL maps with 50 middle school math and science teachers. Teachers selected one of the nine mathematically themed maps and completed a series of tasks (Figure 3), culminating in a presentation they shared with the whole group. In general, teachers felt that the content and process skills covered on the science literacy maps and required by the state curriculum in middle grades mathematics were a good match.

Teachers felt that, although students came to them in middle school having been exposed to the prerequisite skills and content knowledge indicated on the strand maps as areas of focus for earlier grades, they were not proficient with these concepts and skills, and they needed more help and practice with interpreting graphs and data for math and science. Teachers also felt that students needed more assistance with developing a better number sense, gauging whether their answers were logical or not.

The mandated use of calculators on the state's eighth-grade math test detracted from students' ability to develop this number sense. Teachers felt that students were unable to create their own graphs when given a raw data set. Students were unable to manipulate variables and arrived in middle school classrooms with no knowledge of the metric system.

In general, teachers found the maps useful. One group said the maps "put it together in a big-picture sense for us and gave us new meaning." Teachers were pleased with the resources they located on the NSDL website, and several groups were so positive about the activities offered they felt they had only scratched the surface and looked forward to further investigation of the resources. They also liked the design of the site and felt it was user friendly and easy to navigate. Teachers were positive about this professional development experience. They indicated that the Atlas was a good tool to help them step back and take another look at their curricula from a larger perspective than teachers typically do. Our teachers appreciated learning about the NSDL website and indicated that they would be using this website as a resource in the coming school year.

FIGURE 3 Teacher task handout

1. Carefully examine your map and write a brief description of the content and process skills addressed by your map. Overlay your middle school NCSCOS math objectives on the benchmarks (content) and process skills of the Atlas Map. Describe areas that match and areas that do not match.

2. Identify prerequisite knowledge and skills on the map that your students typically have when they arrive in your middle school classroom.

3. Identify prerequisite knowledge and skills on the map that your students typically do not have when they arrive in your middle school classroom.

4. How much time do you spend on teaching/learning the knowledge/skills reflected on this map? Does your county provide you with a pacing guide? If so, how much time does it suggest that you spend teaching the knowledge/ skills indicated on this map?

5. What is your very best, most successful teaching activity that you use to be sure that students have the content knowledge specified on the map?

6. What is your very best, most successful teaching activity that you use to be sure that students have the process skills specified on the map?

7. Examine several of the linked resources and report on one resource that looks like it would be helpful in teaching content and another resource that looks like it would be helpful in teaching process skills.

8. These "math" maps are specific to scientific literacy. Are there missing components of mathematical knowledge or sets of mathematical skills that students need to achieve scientific literacy?

Proportionality should be a central focus of the middle-grades science and mathematics curricula and concepts such as density can be introduced and taught in both disciplines, highlighting for students the connections between science and mathematics. The Atlas of Science Literacy can help science and mathematics teachers bridge the gap and strengthen connections between these two disciplines.

Conclusion

Now that you have successfully completed this activity, you are ready to find out what pennies are made of. It may surprise you! Obtain a copy of the Density of Pennies Activity Worksheet and follow the directions to conclude this activity.

Activity Worksheet-Density of pennies

Purpose

To determine the density of a group of pennies minted prior to 1983 and a group of pennies minted after 1982 through graphical analysis using calculations.

Materials

* set of pennies (25 pre-1983 pennies and 25 post-1982 pennies per group of four students)

* triple beam balances

* rulers

* calculators

Procedure

1. Students are paired in groups of four for this activity. One pair of students works with pre-1983 pennies while the other pair of students works with post-1982 pennies.

2. Group together 25 pennies that were minted before 1983, or 25 pennies minted after 1982.

3. Using the balance, find the mass of 5 of the pennies, and record this mass in the data table. Then, add 5 more pennies and find the mass of 10 pennies. Complete this procedure by adding and finding the mass of 15, 20, and 25 pennies.

4. Measure the diameter and height of the various stacks of pennies to the nearest tenth of a centimeter, and record the appropriate information in the data table.

5. Using the appropriate equation for finding the volume of a cylinder, show the calculations below, and then record your answer in the volume column.

6. Copy the other group's data in your chart and graph both lines. Draw a best-fit line through each set of points and label the lines.

7. Complete your analysis.

Data analysis and summary

1. Graph the information for both groups of pennies in your data table on the piece of graph paper provided. Put the mass on the y-axis and the volume on the x-axis. Use zero as your point of origin, and use the full sheet of graph paper.

2. Draw a best-fit line through your data points, and label this line.

3. Be sure to label your axes, and include a title for your graph.

4. Find the slope of the line. Show your work. (Hint: Remember to use the data for the first and last points in your slope equation.)

5. What does the slope of the line tell you about the density of your group of pennies?

6. What is the formula for density? What units do you use?

7. Why did you put the mass on the y-axis and the volume on the x-axis?

Comparing data

1. Density of the pennies minted before 1983 =

2. Density of the pennies minted after 1982 =

3. Use the table below to answer the following questions.

Metal	Density (g/mL)
Copper	8.92
Aluminum	2.699
Magnesium	1.738
Zinc	714

* The pennies minted before 1983 appear to be primarily composed of what metal?

* The pennies after 1982 appear to be primarily composed of what metal?

4. What other laboratory technique could you use to find the volume of the pennies?

Note: This activity was adapted from the 1995 Laboratory Manual Merrill Chemistry published by Glencoe Division of Macmillan/McGraw-Hill School Publishing Company.

References

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American Association for the Advancement of Science (AAAS). 2000. Atlas of science literacy, Vol. 1. Washington, DC: AAAS and the National Science Teachers Association.

Hassinger, J., and D. Joiner. 2007. The computational science education reference desk. Science Scope 30 (7): 12-15.

National Council of Teachers of Mathematics. 2000. Principles and standards of school mathematics. Reston, VA: NCTM.

Rutherford, J., and A. Ahlgren. 1990. Science for all americans. New York: Oxford University Press.

Resources

National Science Digital Library--http://nsdl.org Density by Graphical Analysis WebQuest--http://schoolcenter.gcsnc.com/ education/components/whatsnew/default.php?sectiondetailid=206419&sc_id=1219873935