water and allowing this water to evaporate will cool the air inside the bottle, causing the air particles to slow down and the air to contract.

All gases, and most liquids and solids, expand when heated and contract when cooled. Exceptions include water expanding as it changes to ice (i.e., cools), a stretched rubber band contracting when heated, and zirconium tungstate (a ceramic) shrinking when heated.

Concept application. Ask students to identify where these principles are used in everyday life. Examples include using hot water to remove a tight-fitting metal lid from a glass jar, leaving gaps between the ends of railway lines to prevent them buckling, and hanging electrical power lines loosely between the poles, as tight lines would contract and perhaps break in cold weather.

Invite students to explain why, when an egg is placed in hot tap water, one or more streams of bubbles rise from the egg. Students might even try this at home prior to their eggs being prepared for breakfast. The hot water causes the air inside the egg to expand and escape through microscopic holes in the shell. If boiling water is used, the air will expand quicker than it can escape through the holes, and the shell will crack. To prepare boiled eggs without cracking the shells, place the eggs in room temperature water and heat slowly.

Pasta Power

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Abstract

A prominent theme permeating national science education reform reports such as the *National Science Education Standards* (National Research Council [NRC], 1996) and *Project 2061: Science for All Americans* (Rutherford & Alhgren, 1990) recommends the incorporation of cooperative learning in the science classroom. Although this pedagogical approach is designed to facilitate and enhance science teaching and learning, various complexities often surround a collaborative environment. The implementation of group-building activities is designed to help teachers provide appropriate structure to group activities, structures which promote equity and fairness in the classroom. This paper discusses a team-building activity that addresses the *National Science Education Standards* for Content Standard E: Science and Technology and serves as a practical, feasible, and engaging activity shaped to encourage the development of cooperative skills.

Introduction

During the past decade, cooperative learning has emerged as a leading pedagogical approach that facilitates science classroom learning experiences. Cooperative learning refers to the use of small groups and teamwork to achieve a variety of academic and social gains in the classroom. Although the roots of cooperative learning can be traced to the 19th century (Johnson & Johnson, 1994), the 1970s noted an onset of a movement toward research on cooperative learning.

Cooperative learning practitioners acquire theoretical support from many educational philosophies and theories (Slavin, 1987), but a significant source of motivation is rooted in social psychology (Deutsch, 1949). Several research reports have revealed the positive effects of student cooperative learning experiences. These effects include higher self-esteem, greater comprehension of content knowledge, higher academic test scores, improved positive social skills, higher student achievement, and reduced stereotypes of individuals of other ethnic groups or races (Johnson, Johnson, & Holubec, 1993; Marzano, Gaddy, & Dean, 2000; Slavin, 1991; Stahl & Van Sickle, 1992). Science education researchers have also conducted studies on the effects of cooperative group problem solving (Heller, Keith, & Anderson, 1992; Heller & Hollabaugh, 1992; Lumpe & Staver, 1995). These researchers discovered that students working in mixed ability groups were able to solve problems at a much higher level than those same students working alone. In addition, the students who worked in collaborative groups were able to develop more coherent conceptual understanding of science topics than those students who worked independently.

Not surprisingly, several science education reform reports call for the inclusion of collaborative learning experiences. For example, cooperative learning is a prominent theme found in the chapter on Science Teaching Standards in the *National Science Education Standards* (National Research Council [NRC], 1996). These standards reveal that:

> working collaboratively with others not only enhances the understanding of science, it also fosters the practice of many of the skills, attitudes, and values that characterize science. Effective teachers design many of the activities for learning science to require group work, not simply as an exercise, but as essential to the inquiry. The teacher's role is to structure the groups and to teach students the skills that are needed to work together. (p. 50)

However, in spite of these positive findings, a cooperative learning environment is very complex, and students can often have difficulty working in groups. For example, teachers may feel frustrated with group work as they inadvertently rush to "cover" the content without investing the necessary time to provide new groups of students with opportunities to practice working together as a team. One common question that many teachers pose is: “How do I get a new group of students to communicate, share information, and work effectively as a team?” Proponents of cooperative learning have applied the term *group building* to refer to a process used to help a new group develop and transition into a highly functioning learning team (Kagan, 1992). Hence, the initial collaborative exercise for a new group should include a meaningful theme to capture the attention of each student. For that reason, the first group experience may often be the most important one, as success here often predicts the teams’ chance for long term success (Vermette, 1998).

The Activity

Pasta Power, the tower building activity described here, provides a non-threatening, group-building opportunity for students to work together and practice communication skills in a setting sure to engage your class. This activity is a wonderful experience when a new group of students form, or during the first week of school. In addition, the use of spaghetti as a building material is inexpensive and offers a motivating and challenging team building experience. Furthermore, this activity is designed to follow the 5Es Learning Cycle Model (Bybee & Landes, 1990). This instructional model has been chosen because of its relevancy to inquiry in science education. The model can be used to design a science lesson that is based upon cognitive psychology, constructivist learning theory, and best practices in science teaching. The cycle consists of the following cognitive stages of learning: engage, explore, explain, elaborate, and evaluate. Rodger Bybee (1997), in his book *Achieving Scientific Literacy-From Purposes To Practices*, declares: “Using this approach, students redefine, reorganize, elaborate, and change their initial concepts through self-reflection and interaction with their peers and their environment. Learners interpret objects and phenomena, and internalize those interpretations in terms of their current conceptual understanding" (p. 176). Although the 5Es Model is used to guide the various phases of this cooperative learning activity, the implementation of cooperative learning can be used with other models of instruction as well.

Pasta Power is appropriate for students in Grades 5-9, and may last approximately two, 50-minute class periods. Several standards are addressed in this activity, including the *National Science Education Standards* (NRC, 1996) for Content Standard E - Science and Technology**:** 1**)** Design a solution or product, 2) Implement a proposed design, and 3) Evaluate completed technological designs or products. This activity also addresses the following standard, for problem solving, of the *National Council of Teachers of Mathematics* (2000): Apply and adapt a variety of appropriate strategies to solve problems.

Preparation

The materials required for this lesson are easy to obtain. Each group of 4 students should have a bundle of 40 sticks of spaghetti and 10 pieces of elbow macaroni. The materials needed for the whole class include two or three mass/weight sets, cardboard or hard stock paper, two rolls of masking tape, and an optional digital camera.

Prior to participating in the tower building experience, each student should be assigned a managerial role, which will help with classroom management issues. Each student in a group may be randomly assigned a number, ranging from 1-4 and corresponding with a particular managerial role, by choosing numbers out of a hat. Table 1 highlights the roles and responsibilities for each student. It is important to clearly define and discuss these roles so that each student understands what is expected of them.

Table 1
Student Managerial Roles

Student number	Role	Responsibility
1	Runner	Gathers and returns group materials.
2	Recorder	Records sketches and drawings for the group. Keeps notes about group progress.
3	Spokesperson	Seeks out the teacher regarding group questions. Responsible for speaking for the group.
4	Timekeeper	Keeps the team on task by paying attention to time.

In addition to discussing the managerial roles, this is also a good time to overview the Cooperative Skills Rubric (Figure 1) and notify students that these skills will be evaluated during the activity. Once the student roles are determined, and cooperative skills have been discussed, the class is ready to begin the activity.

Engagement

Set the tone by reading the following scenario to the class:

> A popular architectural team has hired you to work with a group of architects. Your challenge is to work with your design team to develop a spaghetti model of

a tower. However, your resources are limited. Your team challenge is to construct a freestanding tower that will support the greatest weight for 15 s. Your building materials comprise 40 sticks of spaghetti, 10 pieces of elbow macaroni, and 65 cm of masking tape. Your model must also adhere to the following guidelines: 1) the height of the tower should be at least as high as the length of a spaghetti stick (24 cm) and 2) the top and bottom of the tower must be large enough to enclose a 15-cm square.

(*Please note:* The tower must be freestanding. Oftentimes, students want to tape the tower to a desk or table. The towers are permitted to be higher than 24 cm and the spaghetti and elbow macaroni may be broken or cut apart.)

Exploration

Ask the *runner* of each group to collect the materials at a Resource Center. Encourage the students to communicate to other members of their team and design possible sketches of their tower ideas before they begin the construction of their models. Also, ask the students to inspect the building materials before beginning. Any materials that the students feel are not of high quality, or suitable (e.g., a broken piece of spaghetti), should be replaced. Remind students that they are working with limited resources and should not be wasteful of the supplies. As a safety note, you may want to remind the students not to eat the spaghetti or elbow macaroni.

As the students are working, it is important that you circulate around the room, facilitating discussions, making observations, and providing assistance during the activity. This phase of the activity is a great opportunity for you to assess student cooperative skills. Figure 1 contains a Cooperative Skills Rubric.

Cooperative Skills Rubric

Criterion	**Points**					
	0	**1**	**2**	**3**	**4**	**5**
On task	Never	Rarely	Occasionally	Usually	Frequently	Always
Shows respect	Never	Rarely	Occasionally	Usually	Frequently	Always
Everyone contributing	Never	Rarely	Occasionally	Usually	Frequently	Always
Overall group productivity	-	Much time spent without purpose	Off-track frequently	Barely accomplished the job	Did well once ideas were clear	Highly productive

Figure 1. A cooperative skills rubric.

Explanation

This phase is student-directed. Each group should present their tower design to the rest of the class. The *spokesperson* should address the following:

1) Describe and explain the process your architectural team experienced while making the towers, and
2) Discuss any problems that were encountered and what was done to fix them.

Extension

Finally, we arrive at what is perhaps the most exciting part of the activity; testing the towers. Establish a Testing Center that is visible to all students. Have each group bring their model to the Testing Center. Each tower should be tested to see how much weight (if any) it can hold. One approach to applying weight to the tower is to place a piece of cardboard or hard-stock paper (large enough to cover the top surface area of the tower) on top of the tower. Then, proceed by slowing adding small weights on this surface. Another approach, that may be a bit simpler, is to stack small books or magazines on the top of tower. In order to obtain a fair assessment of the tower quality, the tower should be able to support an added weight for at least 15 s, before more weight is added. Also, it is important to add the same amount of mass at each increment. For example, you may choose to add weight in 50-g increments every 15 s. Or, if using non-standard units, three magazines or booklets can be added every 15 s. Do not be surprised if many of the towers collapse during this phase. However, it is likely that some of the towers are so well built that they hold a great amount of weight.

It is critical to discuss with the students that their assessment is based upon their cooperative skills, and not the tower that holds the greatest mass. After the testing period, the students should return to their desks and address the following reflection questions. These responses can be recorded in student science journals, or turned in as a homework assignment. Possible reflection questions include:

- Why did your tower collapse? What could your team have done to prevent the problems that your tower encountered?
- If your tower did not collapse, what do you think caused it to hold weight?
- What other types of building materials would you like to use?
- What changes (if any) should be made in your design?
- Think about all the towers you observed today. What aspect(s) of the tower designs created stable towers?
- Discuss your experiences. What did you do to contribute to the team?
- What is one thing that your team did today that encouraged you to work on task?

- What problems (if any) did your group experience?

Although the overall purpose of this activity is to promote and practice cooperative skills in an engaging team-building activity, it is inevitable that some students may feel frustrated and unsuccessful if their tower collapses. Since the students have now had time to reflect upon their design and observe other team designs, they are well prepared to revisit their tower and create new towers based upon their observations and learning experiences.

Evaluation

Since the overall goal of this activity is to provide a team-building experience so students can practice collaborative skills, the Cooperative Skills Rubric of Figure 1 can be used to assess these skills. You may also want to provide the rubric to the students and ask them to self-assess their skills and the skills of their teammates. The first three categories on the rubric, *On Task*, *Shows Respect*, and *Everyone Contributing*, are intended to be individual ratings. However, the fourth category, *Overall Group Productivity*, is intended to be a group score. An additional cooperative skills category may be *Praises/Supports Other Team Members*.

An important component to this evaluation phase is the post-activity discourse between the teacher and each group regarding their cooperative skills assessment. It is important to communicate both strengths and weaknesses with the students, as this will foster growth and improvement for future collaborative exercises. If you choose to have students conduct self and peer assessments, a comparison and discussion of their evaluations with your assessment of their skills is also important for their learning and growing process.

Further Extension Ideas

This activity can easily be integrated with other content areas, such as economics, physics, or writing. Here are some ideas for additional extensions.

Economics. You may wish to add an economic component to their construction challenge by requiring the students to “purchase” their materials (with make-believe money). Determine a value for each building material. For example, you may charge $2.00 per stick of spaghetti, 50 cents for each elbow macaroni, and $1.00 per centimeter of tape. Explain to the design teams that their task is to not only build a structure that meets the specifications and holds the most weight, but also to do so at the least cost. Adding this component will not only integrate a real-life, economic aspect into the activity, but also encourage the students to avoid being wasteful of materials.

Physics. This activity may be integrated into a physics unit about structures and designs. For example, concepts such as force, compression, load, and tension can be explored. Students may also research the engineering aspects, and construction, of popular towers around the world (e.g., The Leaning Tower of Pisa in Italy or The Sears Tower in Chicago). Students will be able to develop an understanding of engineering designs as they recognize and apply geometric ideas and relationships. You may even want to introduce the notion of variables to this activity. For instance, invite the students to try to design towers using different varieties of pasta, such as angel hair pasta or fettuccini.

Writing. Create a classroom newsletter that highlights the spaghetti tower models. Have students take digital photos of their towers during the building process. Each group should write an article discussing their tower.

Additional Challenges. Looking for more team building ideas? The *Building Big Activity Guide* (Macaulay, 2000), sponsored in part by The National Science Foundation and Siemens, is an outstanding resource that presents a collection of team-building challenges for students in Grades 5-8. The *Building Big* interactive web site can be found at http://www.pbs.org/buildingbig .

The following have been modified from the *Building Big Activity Guide*. In the *Domes Building* and *Bridge Building* challenges, student teams need to design and build the widest dome possible that will support their science book, and the strongest bridge possible that spans a distance of 50 cm, respectively. For both challenges, offer the following building materials: paper clips, tape, yarn, and straws.

Conclusion and Final Remarks

Many science teachers are raising questions about how to establish cooperative learning teams that maximize student engagement and participation. It is essential to implement team-building activities before new groups of students embark on the academic study of science concepts. Students need to have opportunities to learn and practice collaborative skills. Often, the ability for students to work cooperatively is assumed, and little time is spent establishing effective cooperative learning skills. This assumption usually backfires, and results in groups that are off-task, disrespectful to each other, and unorganized.

Activities such as the one described in this paper served as a critical component to the collaborative design of my former ninth-grade, integrated science classroom, and is also a critical component of my current university science methods courses. I engage my classes with several team-building lessons during the first weeks of school in order to create a collaborative classroom climate. However, when I first began my teaching career, I was unaware of how to implement managerial roles, cooperative learning structures, or methods of assessing cooperative skills. After several frustrating experiences, I began collaborating with colleagues and attending professional development classes aimed at improving my understanding of how to effectively implement cooperative learning in the science classroom. What I learned is that it is vital to spend time on group-building activities that engage and interest the students early in the school year. Investing time through team-building activities helps establish highly-functional cooperative learning teams in the classroom. Also, discussing cooperative skill strengths and weakness with each group is a critical component that helps to solidify the importance of these skills for future collaborative experiences.

My personal experiences are that this *Pasta Power* activity has been positive and effective in promoting the group-building process. However, my students experienced several phases throughout the duration of the activity. Although they initially felt a level of frustration with this new constructivist experience, the students were able to transition to a comfortable level where they were able to embrace the group-building experience. Too often, students are blocked by frustration when they would be better working through it. Because the students were not accustomed to being challenged, they became frustrated and tended to shut down. However, with practice in a non-threatening classroom environment, they can learn to embrace the challenge of a novel problem and enjoy figuring out a solution. This is one of the reasons why it is crucial for teachers to provide these types of experiences early in the school year. It can be expected that the students will encounter challenges with their cooperative skills. However, being a patient facilitator can help them to overcome their weakness. I learned that it is important to be a good listener throughout group-building activities, and to provide alternative solutions that encourage student dialog.

I desired to have cooperative learning become an opportunity for my students to interact with each other, both intellectually and socially. I therefore had to spend the necessary time and energy learning how to establish a cooperative classroom. This learning process takes patience and time. However, the long-term benefit to student learning is well worth it.

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Science Poetry

Reading and/or listening to poems that have been composed by other children their own age can inspire and reassure students as to their ability to understand and write poetry, and the science poems in this regular section of *SER* may be used for this purpose. Please find information about the *International Science Poetry Competition* at http://www.ScienceEducationReview.com/poetcomp.html .

Science

Why do shoes wear out in different places?
And how come the skin is so soft on our faces?

Why does our complicated brain,
Tell us we're in terrible pain?

What causes dust to float through the air,
And cause all the fuzzy bits in our hair?

What are the answers to these questions?
Does anyone have any suggestions?

Everyone, you should take the chances,
As the study of Science has all the answers!

Lauren Maroney, 9 years
Australia