Effectiveness of a Middle School Chemistry Curriculum During Scale-Up: A three-year perspective

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Abstract
Over the past four years, we have been developing the Investigating and Questioning our World through Science and Technology (IQWST) curriculum. This study centers on the 6th grade chemistry unit of the IQWST curriculum entitled “How can I smell things from a distance?” The purpose of this study is to describe our approach to scaling up and evaluate the effectiveness of the curriculum during this process - from a small scale pilot involving a single teacher and her 57 students to a large-scale national field trial involving 28 teachers and 3,000 students. Key features of our scaling-up process include the development of student assessments and professional development for teachers.

Purpose
One of the grand challenges of the 21st century is to develop curricula that help all students gain scientific literacy – including science content and science process skills. In the United States, curricular interventions tend to be developed on a small scale, often involving individual teachers at schools that are convenient to the university and its partner institutions. These small-scale partnerships are highly fruitful, as developers are in close contact with piloting teachers and can constantly provide support and professional development for the interventions. Moreover, these teachers are often a part of the development team and therefore, can provide developers with valuable feedback about which activities worked and which ones need to be changed or modified to work in the classroom. However, these small scale partnerships can also be limiting as many curricular interventions do not reach beyond the classrooms involved in the original study due to many factors, including funding constraints, difficulty in replication to other classrooms and issues related to professional development. Thus, the ability to evaluate the effectiveness of the same curriculum for students from different populations is often lost.

Over the past four years, I have been a part of the development of the Investigating and Questioning our World through Science and Technology (IQWST) curriculum. The IQWST project takes the approach of building student’s understanding of key scientific ideas and practices from 6th to 8th grade (Krajcik, McNeill and Reiser, in press). This study centers on the 6th grade chemistry unit of the IQWST curriculum entitled “How can I smell things from a distance?” The unit focuses on students’ understanding of the particle nature of matter and how the particle model helps students to understand the properties of substances as well as phase changes.

The purpose of this study is to examine the ability of the curriculum to build 6th grade students’ understanding of the particle nature of matter as the curriculum has gone from a small scale pilot involving a single teacher and her 57 students to a large-scale national field trial involving 28 teachers and 3,000 students. I will describe our approach to scaling up and evaluate the effectiveness of the curriculum during this process. This includes describing how professional development has evolved as the number of teachers has increased as well as how changes to the curriculum and assessments were undertaken.

Perspective
The No Child Left Behind Act of 2001 (NCLB) has placed a greater emphasis on the use of assessments to track students’ education progress as well as serving as an accountability measure of schools. In addition, NCLB has called for higher academic
standards. Current science education reform has focused on how to help all students develop scientific literacy. Both the Nationals Science Education Standards (NRC, 1996) and Project 2061: Science for all Americans (AAAS, 1989) point to the need for ALL students to develop scientific literacy. In response, science education research has sought to develop curricular interventions that address these issues. Many of these interventions are effective on a small-scale, but very few studies have attempted to examine the impact of scaling up these interventions onto a long-term, large scale (Barab & Luehmann, 2003).

In recent years, a few research studies have looked at the challenges that arise when a curricular intervention is disseminated to a larger scale (Songer, Lee, & McDonald, 2003; Linn, Clark & Slotta, 2003; Marx, Blumenfeld, Krajcik, Fishman, Soloway, Geier, & Tal, 2004). Each of these learning environments has a common thread, in that technology plays a significant role in the learning process. Songer et al. (2003) found that it made no difference whether teachers were from an urban school recruited to participate in the intervention or teachers who found the intervention on their own and volunteered to participate. Students can achieve similar learning outcomes despite differences in available resources and access to technology. Linn, Clark & Slotta (2003) found that the Web-based Inquiry Science Environment (WISE) has been able to reach 1,000 teachers and 100,000 students because the environment is highly adaptable for the needs of diverse teachers. Marx et al. (2004) found that they were able to succeed in scaling up their inquiry-based science-learning environment for 8,000 students in a large urban school district by carefully developing a standards-based curriculum, including assessments and professional development for teachers aligned with these standards. Each of these studies provide insight into how a curricular intervention can be a means for improving student learning outcomes.

These studies also indicated that there are challenges to scaling up innovated curriculum innovations. These challenges include professional development and support of teachers, meeting the local needs of schools, and adaptability for the needs of differing student populations. This paper furthers previous work by detailing how we addressed many of these issues while scaling up the 6th grade IQWST chemistry over the past three years. In it, we describe the professional development and support provided to teachers, as well as changes to the curriculum and its assessments. In order to determine how this process of scaling up affected student outcomes, we compare pre and posttest learning gains and the effect sizes for each enactment. Thus, we answer the following research question: How does the scaling up of a curriculum affect student outcomes? In other words, how does the scaling up of a curriculum reflect on the effectiveness of the curriculum?

**Curriculum and Assessment Development**

For the development of this unit, we identified three standards (see Table 1) from the Benchmarks for Scientific Literacy (AAAS, 1993) and National Science Education Standards (NRC, 1996). The identification of a small number of standards sets the IQWST curricula apart because of our focus on depth instead of breadth, which has become a hallmark of national standards.
The benchmarks were then unpacked, clarified and elaborated to ascertain what each of these benchmarks means for teaching sixth grade students the particle nature of matter and how the particle model is used to describe the structure of matter and explain phase changes. The process of unpacking these learning goals also helped to identify what ideas needed further support for students. For example, helping students understand that matter is anything that has mass and volume. Understanding what is (and is not) matter is fundamental to help students understand solids, liquids, and gases as well as developing a particle view of matter.

Table 1. Unit Learning Goals

| AAAS 4D/M1: All matter is made up of atoms, which are far too small to see directly through a microscope. The atoms of any element are alike but are different from atoms of other elements. Atoms may stick together in well-defined molecules or may be packed together in large arrays. Different arrangements of atoms into groups compose all substances. |
| AAAS 4D/M3: Atoms and molecules are perpetually in motion. In solids, the atoms are closely locked in position and can only vibrate. In liquids, the atoms or molecules have higher energy, are more loosely connected, and can slide past one another; some molecules may get enough energy to escape into a gas. In gases, the atoms or molecules have still more energy and are free of one another except during occasional collisions. Increased temperature means greater average energy of motion, so most substances expand when heated. |
| NRC B5-8: 1A: A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the substance |

These standards were then used to construct learning goals. These learning goals result from combining the content standard with an inquiry standard. The learning goals clearly specify what students are expected to be able to do with the knowledge described in the benchmark (see Table 2).

The Investigating and Questioning our World through Science and Technology (IQWST) project (Krajcik, McNeill and Reiser, in press) also takes the approach of building student’s ideas over time. Thus, in the 6th grade chemistry unit, students develop and use the particle model to explain phenomena, such as states of matter, phase changes, and properties. For example, the particle model can be used to explain a property like boiling point. The boiling point of a substance occurs at a fixed temperature and involves the rapid evaporation of anywhere in a bulk liquid. During heating, particles gain energy and move faster. The energy of these molecules is enough to overcome the attractive forces of the other liquid molecules so that it goes from the liquid to the gas phase.
Table 2. Example of a Learning Goal

<table>
<thead>
<tr>
<th>Content Standard</th>
<th>Inquiry Standard</th>
<th>Learning Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>…In liquids, the atoms or molecules have higher energy, are more loosely connected, and can slide past one another; some molecules may get enough energy to escape into a gas. In gases, the atoms or molecules have still more energy and are free of one another except during occasional collisions.</td>
<td>Develop…models using evidence. (NRC, 1996, A: 1/4, 5-8) Models are often used to think about processes that happen…too quickly, or on too small a scale to observe directly… (AAAS, 1993, 11B: 1, 6-8)</td>
<td>Students explain phase changes from gases to liquids and liquids to gases on a molecular level.</td>
</tr>
</tbody>
</table>

As such, we designed a unit in which learning the particle model of matter is contextualized through the use of a driving question. The development of a driving question (Krajcik & Blumenfeld, 2006) serves to produce a context for students to learn about scientific phenomena. The development of the driving question also serves to anchor students learning within a context. In situated cognition, knowledge is a product of the situation and activities from which they originate and meaning is derived from the context of their use. Thus, context plays a vital role in situated cognition in that it “shows students the legitimacy of their implicit knowledge and its availability as scaffolding in apparently unfamiliar tasks” (Brown et al., 1989, p. 38). In our unit, students’ knowledge is the basis for instruction and discussion. Thus, instead of teachers trying to locate students’ conceptual ecologies, students’ models provide a window into students thinking. Students’ models are revisited throughout the curriculum so that students can apply both their real-world experiences and what they have learned through experiencing phenomena to their answering of the driving question. Moreover, the anchoring context is revisited throughout the completed curriculum as students gain greater knowledge and understanding of concepts related to the phenomena studied.

The driving question “How can I smell things from a distance?” provides the anchoring context for all of the lessons and is revisited throughout the unit (Krajcik & Blumenfeld, 2006). Throughout the unit, students create their own models to help them answer and think about the driving question. Students experience various phenomena throughout this eight-week unit to help them to gain knowledge and understanding of the different aspects of the particle nature of matter. Peer-to-peer and whole class discussions are utilized to help students discuss and critique their models and understand scientific concepts.

The Smell unit is also designed to be educative for teacher. Educatively curriculum materials are designed to promote teacher learning (Davis & Krajcik, 2005). In this vein, the unit includes “teacher boxes,” text features developed to help teachers understand models (and the particle model in particular), common student ideas and ways to help students with these ideas, and subject matter knowledge. In addition, the unit includes descriptions of the types of discussions they should use to help students in understanding the scientific content, phenomena they are experiencing, and about the models the
students are creating throughout the unit. For each discussion, there is a purpose for having the discussion, suggested questions and a rational for way these questions help student understanding and what ideas the students should gain from the discussion.

As the unit was developed, we also developed pre- and posttests that included both multiple-choice questions and written response items. The process for developing these questions involved aligning unit learning goals with these standards. Assessment items were then developed to match both the learning goal and the standard. We then used the Project 2061 Item Analysis Procedure to analyze whether the items aligned with the learning goals. This procedure included determining whether the item met the necessity and sufficiency criteria: 1) Is the learning goal needed to make a satisfactory response? (necessity) and 2) Is the learning goal enough, or do students need additional knowledge or skills to solve the item? (sufficiency).

During the three years that this study covers, pre/posttests have varied in length, from 23 items in year one, 22 items in year two and 18 items in year three. However, there have been 10 items, eight multiple-choice items and two written response items, which were kept consistent all three years. These items cover the main foci of the curriculum: student understanding of the particle model of matter and applying their understanding of the particle model to explain phenomena (i.e. phase changes, states of matter, properties). The written response items involve students creating their own models to explain phenomena. Changes to these eight multiple-choice items only occurred between year one and year two. Two of the multiple-choice items have not changed at all. The other multiple-choice items have undergone minor changes to make the items clearer. All changes to items were based on analysis of test results (discussed in following sections). The following is the first year (2005-2006) version of an item:

**When a substance changes from a liquid to a solid, which of the following is true?**

- A. The temperature of the substance increases.
- B. The molecules of the solid move faster.
- C. The molecules of the substance change from soft to hard.
- D. The molecules begin to move more slowly.

However, we found that the answer choices for this item were not parallel. Choice A refers to the substance, while the remaining choices all referred to the substance on the molecular level. Thus, we changed answer choice A to also be on a molecular level:

**When a substance changes from a liquid to a solid, which of the following is true?**

- A. The molecules get colder.
- B. The molecules of the solid move faster.
- C. The molecules of the substance change from soft to hard.
- D. The molecules move more slowly.

The items that changed the most were the written response items. They both included multiple parts and included a lot of verbiage. These items were simplified to include less text as well as to be more considerate for students who do not have strong reading skills (See Appendix A).
Methods

Participants

This study reports findings from our last three years work. Table 3 summarizes the participation and professional development for each year of the study. The year one (2005-06) pilot study involved one teacher’s two classes of 57 students in a large Midwest college town who received continuous support from researchers. The teacher only piloted the 6th grade chemistry unit and was provided professional development prior to enactment. A researcher was in the classroom almost every day, videotaping enactment and providing support when needed. In addition, the teacher would also contact us via email with questions, comments and/or feedback. The teacher also filled out evaluation forms to give us feedback on a majority of the lessons. At the end of the enactment, we met with the teacher to go over this feedback. This feedback was one part of the information used to make improvements to the unit.

In year two (2006-07), the pilot national study involved 6 teachers from across the country and their 216 students. This study involved all of the sixth grade units (physics, chemistry, biology and earth science). During the summer, these teachers received a five-day professional development focused primarily on the first unit in the sequence (physics). The other three units, including the chemistry unit, were introduced in three different afternoon sessions. The session for the chemistry unit focused on a few lesson activities that involved modeling, a scientific practice that is a focus for both the chemistry and physics units. Prior to teachers beginning the chemistry unit, they received three days of professional development. In addition to the face-to-face professional development, teachers received online support through a message board where they could post questions and discuss issues with each other as well as researchers. Researchers also videotaped three of the teachers’ enactments. The other sites also received support from researchers through site visits. Teachers also filled out surveys to provide feedback at the end of each learning set as well as at the completion of the entire sixth grade sequence of units.

The year three pilot (2007-08) involved 28 teachers and their 3,000 students (25 teachers and their 1630 students have complete data). Based on feedback from the previous year, teachers received five days of professional development that included two half-day sessions focused on the chemistry unit in the summer. Prior to enactment of the chemistry unit, teachers also received two days of professional development. In addition, teachers received online support as members of an online support group by posting questions, discussing issues and sharing ways to deal with issues that arose during enactment with each other and facilitators. Researchers made visits to a few schools, but not all schools had available local support.

Table 3. Study Participation

<table>
<thead>
<tr>
<th>Year</th>
<th>Teachers</th>
<th>Professional Development</th>
<th>Students</th>
<th>School Recruitment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1</td>
<td>1</td>
<td>Continuous support</td>
<td>57</td>
<td>1 teacher in a school</td>
</tr>
<tr>
<td>Year 2</td>
<td>6</td>
<td>2 days + online support</td>
<td>216</td>
<td>6 schools</td>
</tr>
<tr>
<td>Year 3</td>
<td>26</td>
<td>2 days + online support</td>
<td>1740</td>
<td>19 schools</td>
</tr>
</tbody>
</table>
The teachers have had a wide range of experience in piloting reform-based curricula (from 0 to 5+ years). The students were from various ethnic and socioeconomic backgrounds and differing academic abilities all three years.

**Instruments**

We developed pre- and posttests that included both multiple-choice questions and written response items. Multiple-choice items covered the key learning goals of the unit: particle nature of matter, matter, phase change, and properties. The ten items that are a part of this study focus on the particle model of matter and applying the particle model to explain phase changes and properties. We created rubrics to analyze students’ responses to the two open-ended questions. For all years, the total maximum score for the written response items is the same as that for the multiple-choice items. Thus, although there are different rubrics for each year, the written response items are weighted to equal the same number of points (four points maximum for each question).

There were two scorers for the written response items. We randomly sample 20% of these open-ended questions, which are then scored by a third independent rater. Percent agreements are used to estimate inter-rater reliability for each open-ended item. Inter-rater agreement has been above 90% for each question for the first two years. Inter-rater agreement has not been completed for the current year’s data.

**Procedure**

We print the assessments with the unique student ID and name for all the students who participate in the project, and mail them with a return envelope to teachers. Each teacher administers the tests and sends her/his students’ responses back to us. We communicate with the teachers by email and phone to ensure that they correctly follow the assessment procedure, and to resolve any problems teachers face. The returned student response sheets are scanned to store students’ responses in an electronic format, such as an Excel file, using Scantron.

The results of the data analysis as well as the feedback from teachers are used to make changes to the curriculum. In the first year, the feedback was primarily used to clarify the teacher materials in terms of helping the teacher understand important chemistry concepts. For example, we include a “teacher box” in the materials to explain the relationship between energy, molecular motion and temperature. The teachers indicated that the information provided in the box was unclear, so changes were made to clarify the information. Changes were also made to student materials (readings and activity sheets). Most of the changes to these materials were to reduce redundancy of activities, develop clearer instructions and to make reading materials more understandable for students. In addition to changes based on feedback from the teacher, changes were also made to make terminology more concise and clearer links to other units in the sixth grade sequence. These changes were made since the unit would now be taught as a part of the entire sequence.

The results of data analysis from year two were used to make changes to the unit. These changes included making materials more concise for teachers and students. In addition, additional changes were made to educative features of the curriculum to aid
teachers in understanding important concepts. Changes to student materials included shortening the introduction of activities to only include the purpose of the activity.

**Data Analysis and Results**

A paired samples t-test was used to examine the change in students’ knowledge of key learning goals. Table 4 provides the overall learning gains for students in year 1. The total score is the sum of scores on written response items and multiple-choice items. Overall, students achieved significant learning gains from pre- to posttest (p <0.001). Effect sizes also indicate that students are gaining significant knowledge of both content and practice (written response). There was no significant difference between the gain scores of males and females.

Table 4: Overall Student Learning Gain, 2005-2006 (n=57)

<table>
<thead>
<tr>
<th>Items (Max Score)</th>
<th>Pretest Mean (SD)</th>
<th>Posttest Mean (SD)</th>
<th>Gain (SD)</th>
<th>Effect Sizea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (16)</td>
<td>5.94 (2.31)</td>
<td>12.75 (2.50)</td>
<td>6.81 (2.89)</td>
<td>2.95</td>
</tr>
<tr>
<td>Multiple Choice (8)</td>
<td>3.26 (1.93)</td>
<td>6.95 (1.54)</td>
<td>3.68 (2.16)</td>
<td>1.91</td>
</tr>
<tr>
<td>Written Response (8)</td>
<td>2.77 (1.09)</td>
<td>5.80 (1.39)</td>
<td>3.01 (1.61)</td>
<td>2.76</td>
</tr>
</tbody>
</table>

aEffect size calculated by dividing gain score for each score by standard deviation (SD) of the pretest for that score.

In year two, as expected students overall learning gains were slightly lower (see Table 5). Students made significant gains in both their understanding of concepts and modeling, although effect size for the modeling related open-ended items are not as great as year 1. Again, gender made no significant difference in gain score.

Table 5: Overall Student Learning Gain, 2006-2007 (n=216)

<table>
<thead>
<tr>
<th>Items (Max Score)</th>
<th>Pretest Mean (SD)</th>
<th>Posttest Mean (SD)</th>
<th>Gain (SD)</th>
<th>Effect Sizea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (16)</td>
<td>6.72 (2.21)</td>
<td>11.24 (2.49)</td>
<td>4.51 (2.43)</td>
<td>2.04</td>
</tr>
<tr>
<td>Multiple Choice (8)</td>
<td>3.06 (1.64)</td>
<td>5.99 (1.76)</td>
<td>2.94 (1.96)</td>
<td>1.79</td>
</tr>
<tr>
<td>Written Response (8)</td>
<td>3.67 (0.95)</td>
<td>5.25 (1.07)</td>
<td>1.58 (1.07)</td>
<td>1.66</td>
</tr>
</tbody>
</table>

aEffect size calculated by dividing gain score for each score by standard deviation (SD) of the pretest for that score.

In year three, there was an expectation of lower gains due to lower support across all sites as well as fewer opportunities to monitor how closely teachers followed the curriculum. Students show significant gains in their knowledge of the particle model of matter, but not as great as the previous two years (see Table 6). As in previous years, there is no significant difference in students’ gain scores based on gender.
Table 6: Overall Student Learning Gain, 2007-2008 (n=1630)

<table>
<thead>
<tr>
<th>Items</th>
<th>Pretest Mean (SD)</th>
<th>Posttest Mean (SD)</th>
<th>Gain (SD)</th>
<th>Effect Sizea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (16)</td>
<td>6.81 (2.58)</td>
<td>10.21 (3.08)</td>
<td>3.40 (2.68)</td>
<td>1.32</td>
</tr>
<tr>
<td>Multiple Choice (8)</td>
<td>3.42 (1.74)</td>
<td>5.41 (2.02)</td>
<td>1.99 (2.07)</td>
<td>1.14</td>
</tr>
<tr>
<td>Written Response (8)</td>
<td>3.39 (1.37)</td>
<td>4.80 (1.08)</td>
<td>1.41 (1.39)</td>
<td>1.03</td>
</tr>
</tbody>
</table>

aEffect size calculated by dividing gain score for each score by standard deviation (SD) of the pretest for that score.

Over the past three years, changes have been made to the curriculum materials. However these changes did not affect the focus or content of the various lessons. Changes that were made were to make concepts clearer for both students and teachers. Based on teacher feedback, changes were also made to how the professional development was conducted between years two and three. It is difficult to determine what affect these had on teacher performance.

Each year, students have improved their performances significantly from pretest to posttest, indicating the curriculum materials are effective. Eighty-four percent of teachers (21) had an effect size of greater than 1. All of these teachers come from schools with varying populations from the southwest (Arizona and Texas), Midwest (Illinois and Michigan) and the south (Florida). These schools also represent urban, suburban and rural school districts and range in population from majority white to majority minority.

However, there were four teachers whose enactments of the curriculum had average effect sizes ranging from 0.41 to 0.74. These teachers are all in middle schools in the same district, but not all are from the same schools. Class size does not seem to be a factor as they range in class size from small to large. Further investigations are necessary to fully elaborate the causes of these reduced effect sizes.

Conclusion

Curricular interventions are aimed at helping students to gain broader understanding of complex scientific concepts and practices. Challenges faced in the scaling up of curricular interventions include professional development and support of teachers, meeting the local needs of schools, and adaptability for the needs of differing student populations. This study provided the opportunity to evaluate whether these challenges have been addressed. It also describes how this curriculum and our support of teachers evolved as the number of participants and schools involved have increased from a local to a national level. In sum, through this study we have shown that a curricular intervention, along with professional development, online teacher support, lead to significant learning outcomes for students from a broad range of backgrounds, even during scale-up.

Student outcomes only provide one part of the picture in determining the effectiveness of a curricular intervention. Teachers play an important role in the effectiveness of the materials. As Ball and Cohen (1996) illuminate, curriculum materials have a unique place in practice in that they can be educative for teachers, can be a means for improving instruction and improve teacher learning through the development of a
partnership with curriculum developers. Throughout our development process, teachers have played a vital role in changes to curricular materials and assessments by providing feedback on what works, what doesn’t work and contributing to teacher materials through examples of classroom activities that they use to help students learning.

Lessons Learned

As a project grows larger in size, the level and ability to support teachers in adjusting to new curricula becomes more difficult. The ability to observe teachers as they enact curriculum provides both the developer and teachers insight into the effectiveness of the curriculum. We are now entering our second year of national field trials. This will provide us with better insight into the effectiveness of the materials themselves, as well as what teachers have learned from them.

Although not the focus of this study, partnership with a publisher and materials providers also factor in the ability to have a successful enactment. Improvements to student and teacher materials must be made within a deadline, which poses a challenge when one has limited personnel. In addition, equipment must be delivered to teachers in a timely manner in order for a successful enactment. The developer has limited control over these factors.

Curriculum materials provide a unique opportunity to be in partnership with teachers, developers, publishers and science equipment providers. As materials are scaled up to larger numbers of teachers, schools, and districts, the challenges faced increase exponentially. This study is just one part of the story. As the national field trials continue over the next two years, we have the opportunity to visit more teachers and districts. In addition, we will have the opportunity to further examine student outcomes using Hierarchical Linear Modeling (HLM).

We will use HLM for analyzing some of the data because of its hierarchical structure. For this analysis, each student will be nested within teachers. Hierarchical Linear Models are designed to analyze systems in which lower level units of analysis are nested in higher-level units of analysis (Raudenbush & Bryk, 2002). Hierarchical Linear Models first make predictions about higher-level parameters, which are then used to make predictions about lower level parameters. In the analysis, the variance associated with teachers and the variance associated with individual students can be separated in the analysis. It will present genuine effects of IQWST on student learning by eliminating teacher variance with separate regression equations at each level of the model (e.g., teacher level and individual student level).

References


Appendix A: Example of Written Response Change

2005-2006 Test
1. Bill and Shauna noticed that Bill’s room was a lot colder than Shauna’s room. They wondered if you could smell an air freshener faster in a cold room or a warm room. They decided to do an experiment: Bill plugged a lemon air freshener into the wall in the cold room. At the same time, Shauna plugged a strawberry air freshener into the wall in the warm room. (The air fresheners were the same distance away from the bedroom doors.) Then Bill and Shauna sat near the bedroom doors. From which room could they smell the odor first?

   A. First, circle which room Bill and Shauna would smell the odor from first:
      Cold Room   Warm Room   Both at the same time   Neither of the rooms

   B. Second, draw models that show why you chose your answer in part A. (Your models should show how the odors moved in the cold room and in the warm room.)

   C. Third, explain in writing why you chose your answer in part A. (Your explanation should describe how the odors moved in the cold room and the warm room.)
1. Bill and Shauna wondered if they could smell an air freshener faster in a cold room or a warm room. They decided to do an experiment: They made the room cold (50°F), plugged an air freshener in, and measured the time it takes for the smell to reach the door. The next day, they made the same room hot (85°F), plugged in a new air freshener, and again measured the time it takes for the smell to reach the door.

A. What do you think would be the results of Bill and Shauna’s experiment? Circle one of the following options:
   1. The smell reaches the door at the same time in both temperatures
   2. The smell reaches the door faster at 85°F
   3. The smell reaches the door faster at 50°F

B. Second, draw models that can help you explain your choice in part A. (Your models should show how the odors reach the door at lower temperatures and higher temperatures)

Make sure to label the different parts of your model Key:

C. Use your model to explain why you chose your answer in part A. Your statement should show how the odors reach the door at lower and higher temperatures.