# Hands-on Science
# Pilot Project

*by*
*Roshni Kasad*[1]

*28th August, 2004*

[1] Roshni Kasad graduated in 2002 with a biology degree from the University of Delaware. In 2003, she came to India to do a year of service as an Indicorps fellow. She focused on science education, particularly in rural areas. Upon completion of her Indicorps fellowship, Roshni returned to the States to obtain her PhD in Molecular and Cell Biology at the University of California, Berkeley. Her year in India instilled in her a strong passion for equity in education.

# Table of Contents

Hands-on Science project[2] background

The goal of the Hands-on Science pilot project is to incorporate more practical learning into the high school science curriculum. Students gain a better understanding of the real-life applications of science, while realizing that science education can be fun and exciting. This report is based on 10 months in the field (October 2003-July 2004), during which I worked in rural Patan, Gujarat with 5 village high schools.[3] While my focus has been on 8th and 9th standard students, an integral part of this project is to encourage science teachers to focus more on experiential and activity-based learning. My project work includes critical observation of the existing education system, as well as my own efforts at teaching hands-on science.[4] Part I includes my observations of the existing education system. In Part II, I discuss my efforts at teaching hands-on-science, including small group learning and themed lessons. Part III offers my conclusions and recommendations. This includes training teachers on how to create a more stimulating and enjoyable learning environment.

## Part I: Observations of the existing education system

I observed in mostly high school (but also primary school and college) classrooms in order to understand the predominant teaching styles and classroom environment. I found the teaching style to be heavily biased towards a lecture-based structure, with teachers often lecturing straight from textbooks. In many classes, students were encouraged to memorize verbatim what the teacher dictated. Teachers and students told me repeatedly that the ultimate goal was for students to produce high test results.

### *Lecture-focused classrooms*

I saw a prime example of this lecture-based teaching approach in a *samaj vidhya*[5] class. The 45-minute period was organized in the following manner: the teacher wrote condensed notes (an outline) of a section from the textbook on the board; the students copied the notes in their notebooks; about 8-10 students in a row, one-by-one, read the notes aloud verbatim; and the same process was repeated with a new passage. The teacher later told me that these were "middle intelligence" students who are not capable of memorizing everything in the book. Thus, he gave them these short notes that they can memorize for their exams. When I pointed out that the students are memorizing without necessarily understanding, *gokanpathi*, he agreed. However, he reasoned that these were "middle-road" students who did not know how to engage in self-learning.

---

[2] Hands-on Science is a joint endeavor by the Gujarat Education Ministry, Indicorps, and World Teach.
[3] Tribhuvan, KK Patel, BK Amin, C.A. Panchal JayBharti Vidyalaya, and Ramji Vidyalaya high schools (See Appendix 1 for more details).
[4] It should be noted that my observations and results are based on working only with rural, semi-government schools. I have not had enough exposure to urban schools to assess whether my results would be similar or different there.
[5] Social studies

The samaj vidhya class discussed above is typical of many classes I observed where teachers fed information to students and students were expected to absorb it without necessarily understanding or analyzing it. I rarely saw teachers encourage students to ask questions, to think more in-depth about the lecture, and/or to formulate their own opinions. For the most part, students did not seem actively engaged.

During my tenure, about once a week, science teachers took their students to the laboratory for an exercise that was not entirely lecture-based. The laboratory exercises often involved a teacher doing a demonstration surrounded by forty plus students who tried to get a glimpse of what was happening in the experiment. Most often, students did not handle any equipment or try the experiment themselves. Having students conduct experiments themselves might have made the exercise more effective in giving them an understanding of the scientific principle. Hands-on learning is also significantly more exciting and enjoyable than passive participation.

*Students learn from mistakes*

Often times, the classroom environment seemed stifling and strict, with teachers not being tolerant of mistakes or wrong answers. I often heard teachers tell students not to speak in class unless they were sure they had a correct answer to offer. Students were inhibited and resistant to speak up in class. After a few classes, one science teacher I worked with began to realize that students should be allowed to make mistakes so that they can learn from them. We agreed that often, just because a student gives the correct answer does not mean he/she understands why it is correct. In contrast, students who correct their own mistakes have a better understanding of the concept. The latter students have gone through a logical thought process to understand the reasoning of the answer.

*Questions in the classroom*

One major component lacking from student-teacher interactions was students asking questions. Early in the project, I did an exercise with both $8^{th}$ and $9^{th}$ standard students on the importance of asking questions. There are two types of questions students can ask in the classroom: 1) clarification questions where the teacher is asked to re-explain an idea, and 2) further learning questions, where the student asks the teacher to expound upon what the teacher has already explained. The former requires humility on students' parts to admit that they do not understand. The latter requires the student to take a significant interest in what was taught and to have some critical analysis abilities to probe the topic further. I asked students why they do not ask questions in class; the most common answers were that they were too embarrassed and did not want to look dumb. (See Appendix 2, *The importance of asking questions* lesson plan, for more details).

*Students' hesitancy to approach new problems*

In general, students showed a lack of independence and self-confidence, unwilling to give their own opinions or to take risks to solve problems independently. This behavior was reinforced by teachers who provided answers to students without encouraging them to think for themselves. When students did not know an answer, the teacher immediately gave it to them, rather than guiding them step-by-step through a logical thought process that would allow students to figure out the answer for themselves. Teachers also noted that the widespread use of answer solution guides has led students to be lazy when it comes to solving problems independently. When students study, they immediately go to their guides to find the method of solving a problem, rather than trying to figure it out on their own. This resulted in students to giving up easily on doing a problem that looked remotely difficult or foreign to them.

An example of this hesitancy to take risks arose when I asked my 8$^{th}$ standard students to calculate the circumference of the earth. I gave the students the diameter, and together, we agreed on the formula for the circumference. I plugged the numbers into the equation on the board and asked students to figure out the simple math (multiplication and division). In all 5 schools in which I taught this lesson, at most, 1 or 2 students per class calculated the correct answer. Most students did not even want to try, claiming they did not know how to do the problem. They repeatedly asked me to solve it for them. I was perplexed as to why 8$^{th}$ standard students thought they could not solve a problem that requires only multiplication and division skills. After talking to other teachers, I realized that they often solve example problems on the board and then ask students to solve similar problems on their own. Because I did not demonstrate a similar word problem, students possibly did not know how and/or did not want to take the risk to apply their skills to the new math problem.

*Student motivation and life goals*

Students continually told me that their main goal in school was to achieve high test scores. If they did well in school, they could then get a well-paying job, the ultimate goal. In a predominantly farming community, where income depends on how much rain falls, receiving a steady income is a main concern. When I ask students what they want to do after studies, they were almost surprised that I would ask such a question. The word "want" implies that students have a choice in deciding their future and thus, have the luxury of to take an interest in one field over another. For the most part, these students said that their test scores would determine what they would continue in. It is common knowledge that students receiving the highest scores will go into medicine; engineering comes next, followed by B.Sc., and B.A. Students did not choose to do a Bachelors of Arts because they like the humanities; rather, their lower test score predetermined what line they followed.

A subset of students (mostly female), would tell me their goal is to train to be a primary teacher. I worked in predominantly Patel communities where becoming a primary teacher is extremely common among the educated females; however, the abundance of primary teachers within this community did not seem to be linked to a strong desire to be an educator. Instead, the reason that many advocated this profession was that training time is minimum (only 2 years) and that upon graduation, finding a job is guaranteed (currently, primary school teachers are in demand).

**Part 2: My experiments with teaching in the classroom**

My weekly schedule was structured so that I spent one day teaching at each of the 5 high schools. Each week, or lesson cycle, I developed and taught two lessons, one for 8$^{th}$ standard and one for 9$^{th}$ standard science. The same lessons were taught across all 5 schools. Initially, I was making sure my lessons fit into the syllabus. Further into the project, teachers gave me more flexibility to branch off into topics that were not necessarily covered in the syllabus. The lessons I taught were ones I created on my own and/or were adapted from ones I saw on the internet or in books. I taught on a wide variety of topics, ranging from evolution, pollution, to basics about the earth. While the topic always changed, I tried to ensure that each lesson involved some sort of activity or experiment that attempted to engage and excite students about learning science. The activities I planned required low-cost and locally available materials, making it more feasible for the project to be replicable and sustainable.

*Typical hands-on science lessons*

Working with simple materials and doing simple activities can go a long way to demonstrate scientific concepts to students. An example of this is the pinhole camera experiment I did with 9$^{th}$ standard students. This experiment is frequently done in American schools and requires only a tin can, masking tape, wax paper, rubber bands, and black construction paper. With just these materials, students can make a simple camera in less than 10 minutes. The students, not to mention teachers, were thrilled to play and experiment with the cameras, and at the same time, they were learning important concepts about light and lenses. (See Appendix 2, *Pinhole camera* lesson plan for more details).

Another interactive lesson I did with my 9$^{th}$ standard students was on heritable characteristics. I started off by introducing the concept of a gene, a fairly difficult one to grasp. Through an activity that emphasized the practical implications of genes, students were able to understand basic concepts in genetics. The activity was simple: survey the class for a variety of heritable characteristics, calculate the frequencies of each trait within the class, and compare the class frequencies to known population frequencies. Testing out the traits was the fun part for students. We looked at characteristics such as handedness (left-handers and right-handers), eye color, and tongue rolling (whether or not a person can roll their tongue lengthwise is genetically determined). Each time we saw trait variation within the classroom, we accounted it to variation within genes. For days after, I had students coming up to me and rolling their tongues at me and talking about genes. Through a fun activity, the students took an interest in learning about genetics and remembered the concept. (See Appendix 2, *Heredity—genes and physical characteristics* lesson plan for more details).

*Small group learning*

Initially, my teaching approach focused mostly on group learning. I had a standard format: I introduced that day's topic and gave a background on it for 5-10 minutes; students broke up into groups and were assigned problems to work on independently; and at the end of the lesson, students re-grouped to share their solutions with the entire class. I liked this method because it encouraged the students to learn independently, feel less inhibited in voicing their opinions, and cooperate with each other.

I soon found many problems with implementing the group-learning method. First, it was logistically difficult for a single teacher to facilitate small-group learning. In classrooms of up to 50 students, it was often unrealistic to expect a teacher to ensure that all groups are focused and productive. Even when this method is used in American college classrooms, an upperclassman, who has already taken the course, is assigned to each group to keep the discussion focused. Second, students had difficulty accomplishing simple tasks in groups. They were used to answering problems by reciting verbatim what they had learned from lectures or textbooks. Often times, the type of problems I gave them required students to synthesize information from their daily lives, which was uncharacteristic of their usual classroom routine. Thus, students were again hesitating to approach a new type of problem.

I conducted an $8^{th}$ standard class on conservation of natural resources in the group-learning format. Before breaking into groups, I talked to the class about what natural resources are, examples of them, and about renewable versus nonrenewable resources. In their groups, students had to answer the following: 1) What resources do they use in their everyday lives? 2) Is each resource renewable or not? 3) Is there an abundant supply of each resource or not? and 4) If the supply of the resource is low, what measures can we take to make sure it does not completely run out? Rather than thinking of what they use in their own lives, most students simply responded with the same examples I gave in my background talk. Despite listening to the classroom teacher's and my examples of renewable and non-renewable resources, students often could not determine this for themselves about other resources.

When groups reported their solutions back to the entire class, it seemed as if they were under pressure to produce their answers from memory. Students would "steal" answers from other groups, worrying that their response was incomplete. Groups sat busily perfecting their own answers, while another group was sharing their ideas with the class. There was more of an unspoken competition to have the best answer, rather than a discussion-like format where all students had the chance to express their ideas and listen to each other.

My time constraints were limited because I had only a half hour a week to work directly with each class. In that short span, it was difficult to get students to be adept at working in groups. A more formalized approach to implement group-learning was through a separate 3-month group-learning project that Jayantiben Ravi[6] initiated in three of my schools: BK Amin high school, C.A. Panchal Jay Bharti Vidyalaya, and Ramji Vidyalaya. One 8th standard class at each school was broken into mixed-gender groups of about 5 students each. Students of mixed academic ability were placed together, so that all groups would be on equal footing. Teachers were instructed to teach these classes all day in every subject using only the group learning approach. Within each group, a rotating leader was picked to keep the group on task.

I saw mixed results in this project. I observed, for example, some language classes where entire passages that were normally translated only by the teacher were now being broken up into sections; each group translated its own section and then taught it to the rest of the class. The students were often fairly efficient at doing this independently. In some schools, teachers told me that they were finishing their syllabus early, because the students were getting through the passages faster when working in groups.

I also observed many classes where students would be sitting on the floor in their groups, while teachers taught in their same traditional "chalk-talk" style. Many teachers were confused as to how to teach their particular subject in groups, never being trained on how to do so. Teachers were also often frustrated with a lack of response from the students whom they often labeled as unmotivated and unwilling to learn.

In place of small-group learning, I often worked with the class as a whole. I led the class in a manner in which I was always trying to get a response out of the students. As each step in the lesson progressed, I tried not to introduce and to explain the next concept myself; instead, I indirectly prompted the students to figure out the idea themselves, leading them through a logical thought process.

Initially, I thought having the students work in groups would make them less inhibited and more comfortable to share their own ideas; however, I found that students speak more freely when we work together as a class because I am there every step of the way to motivate and encourage them. In small groups, students often did not provide this kind of support for each other and did not take the initiative to speak on their own. Working together as a class ensured that all students were being exposed to all the concepts. In contrast, when students worked in small groups, they often did not focus on or accomplish the task. This is not to say that group work is not an effective or valuable approach; instead, it was not always the appropriate teaching approach for me to use because of the nature of my short-term project. I had limited time to teach students how to work in groups efficiently and wanted to focus more on hands-on activities that did not have to be group-based.

*Themed lessons*

At the start of my project, I tried to ensure that my lessons fit with the current class syllabus. Because I taught only one day a week at each school, I would often teach new topics that were

[6] Jayantiben Ravi was the Commissioner of Higher Secondary Education in Gujarat the duration of the Hands-on Science pilot project.

unrelated to the previous week's topic. This made it difficult to assess how much the students absorbed from the previous week. For this reason, I experimented with themed lessons, a series of lessons on a broad topic. With my 8th standard students, I taught a series of lessons on the earth. Over a 4-week period, we made model globes. We also talked about the earth's rotation on its axis, its orbit around the sun, and the changing of the seasons, among other things. All the concepts were connected to and reinforced by each other over a few weeks, allowing me to ensure that students had grasped the fundamental ideas.

For example, we always started off the earth lessons with two students acting out the interaction between the sun and earth. In the first lesson, this was done to demonstrate earth's rotation on its axis while it orbits the earth (something students previously had difficulty visualizing). We built upon this model when talking about time zones. The front half of the student playing earth was where India was located and the back half was where America was located. As "earth" shifted positions, we discussed time changes in India and America. In our last lesson on the earth, we discussed seasons, again focusing on this earth and sun demonstration model for clearer understanding. Repeatedly presenting this model engrained in students' minds how the earth is positioned in space. Building upon this same model to discuss multiple aspects of earth demonstrated to students how integrated seemingly different concepts are. Students consequently gain a more comprehensive understanding of all the concepts.

*Activity-based learning that is affordable*

Activity-based learning in science classes does not always require the use of expensive laboratory equipment. A prime example of this is a lesson I taught on the atom to 9th standard students. My students had been working on a basic chemistry unit with their classroom teachers for about two weeks when I gave this lesson, and yet, they could not accurately tell me where atoms are found or what matter is. We discussed how matter and atoms are found in our everyday lives and then went into an interactive activity, which required only the use of student demonstrators. Students, themselves, represented the various atomic particles and positioned themselves within a model atom drawn on the ground. (See Appendix 2 *Introduction to the atom* lesson plan.) Through this type of demonstration, the students were clearly able to visualize an atom. More importantly, the use of their own bodies in the activity helped students remember the concept. More and more educators are now indicating that being physically active and using one's own body in the classroom is a valuable memory trigger.

## Part 3: Conclusions and key recommendations

The main goal of the Hands-on Science project was to implement new teaching stratagies to effectively engage students in the classroom. The hands-on activities and experiments we did in class often gave students a better understanding of the concepts, as well as ensured that the idea remains with them after the 40-minute class period is over; however, there are many obstacles to making this project sustainable and to scaling it up.

Some obstacles Hands-on Science faces:

1) *Teacher motivation*—Activity-based learning requires more preparation and creativity on teachers' parts. It requires self-initiative, which many teachers lack. A large portion of teachers enter the profession for a stable paying job, rather than with the goal of imparting education on students. They are unhappy about issues like low-pay and additional job requirements that the government imposes on them.
2) *Pressure to finish the syllabus*—For teachers who are motivated to teach by activities and experiments, the prime complaint is that the heavily content-focused syllabus does not permit time. Activity-based learning requires more time, and teachers already feel pressured to cover all the topics in the textbook before exam time.
3) *Exam-focused curriculum*—Hands-on science does not directly lead to high test scores in the current system, where exams are factual, rather than analytical based. True understanding of a concept is demonstrated when students are able to explain it in their own words and apply the concept to a new situation. Under the current system, only textbook definitions and explanations are marked correctly on exams, and most exam questions come from study guidebooks and previous exams[7] and thus, are not new to students. The analytical skills students learn through the practical-based learning are not reinforced by the exam system. In a system where students will not succeed unless they receive high test scores, there is no direct benefit for students or teachers to focus on practical-based learning.
4) *Lack of teaching resources and exposure to different teaching methods*—A vast amount of literature is available on activity-based learning in science; however, village teachers have very little access to such resources, often not knowing they even exist. They thus, have only their textbook, as well as maybe a few other resources from their school library (if they are lucky to have a library), to develop lesson plans. This puts teachers in a difficult situation to create activity-based lessons.
5) *Absence of comfortable learning environment*—For activity-based learning to succeed, students need to feel comfortable in the classroom. They need assurance that if they make a mistake, the teacher will not embarrass them in front of the class. Teachers need to allow students the freedom to speak freely and express their individual opinions. Most classroom environments are quite traditional and teacher-centered, rather than student-centered.

Despite all the obstacles, there is precedence for implementing practical-based, joyful learning in the classrooms on a large scale. In the Hoshangabad district of Madhya Pradesh, Eklavya implemented such a project in 16 pilot middle schools in the early 1970s.[8] The project, called the Hoshangabad Science Teaching Programme (HSTP), was running for nearly 30 years and

---

[7] Though teachers and students said there might be slight variation in the question, such as changing the numbers in a math problem.

[8] The project was initially a collaboration of two organizations, Friends Rural Centre and Kishore Bharati, with the State government. Eklavya, an education-focused institute, later took over for the two non-governmental organizations.

had been scaled-up to involve roughly 1000 schools in 15 districts across Madhya Pradesh.[9] Key reasons for the success of HSTP was that Eklavya was given the freedom to use their own practical-based textbooks and to develop their own analytical-based exam system. Government teachers in HSTP underwent intensive training on how to implement the practical-based learning teaching method. Eklavya provided teachers with the necessary knowledge to make teachers feel confident in performing experiments in the classroom.[10] Another integral component was that Eklavya held monthly meetings so that HSTP teachers had a chance to discuss their own experiences in the classroom and to discuss anticipated problems for the upcoming month's lessons. This provided a support system for government teachers and also helped them develop into a team that was sincerely dedicated to implementing hands-on science.

To implement Hands-on Science on a larger scale, HSTP is a solid, tested model to follow. The next phase should be to choose a subset of about 15 interested schools within the Patan district to continue the project. Intensive, continuous teacher training would be required for the science teachers at these schools (Appendix 3 offers suggestions for a few specific training sessions). Looking to non-governmental organizations involved in educational research and experiments (i.e., Eklavya) for guidance on how to conduct training would be advisable. From my experience, government teacher training sessions are planned and conducted by staff who are inexperienced in teaching pedagogy and do not necessarily understand the problems teachers face in the classroom. Knowledgeable individuals outside of the government would be of immense benefit. Building a strong network by having the teachers meet regularly to discuss the project progress is necessary. Using practical-based textbooks that focus less on factual information and completely revamping the science exams to be more analytical based would be ideal; however, this is difficult to accomplish in a high-quality manner. Once a strong base has been built within the 15 involved schools, the involved teachers can then be used to train teachers in other schools within the district.

I have observed positive aspects of the Gujarat education system. I have seen a subset of teachers create open and comfortable learning spaces for students. I have worked with teachers who are sincerely dedicated to the growth of their students. However, these teachers could be even more effective if given a wider range of teaching methodologies and a mandate to focus on the process of learning, rather than solely achieving high test scores. By incorporating more hands-on learning into the classroom, students will be more likely to excel and reach their potential.

---

[9] HSTP was shut down by the government in 2002 when the State decided it best that all State government schools use the same curriculum. Rather than the activity-based Eklavya curriculum, the State chose to use its own standard, traditional curriculum. The shut-down was a messy affair, as some suspected politics played a role in the decision.

[10] Many teachers were initially hesitant to do experiments in the classroom because they felt weak in the subject matter. Eklavya staff taught teachers the experiments incorporated into the curriculum during training sessions; thus, the teachers felt more confident doing the experiments in the classroom.

# Appendix 1: Schools involved in Hands-on Science pilot project

| School | VILLAGE | SCHOOL PHONE NUMBER | PRINCIPAL | SCIENCE TEACHER(s) | CLASSES WORKED WITH |
|---|---|---|---|---|---|
| Tribhuvan | Lanva | 2734-263375 | Bogibhai Patel | Maheshbhai Patel, Bardevbhai Patel | 8A, 8B, 8C, 9B |
| KK Patel | Palasar | 2734-263393 | Hasamatiben Patel | Girishbhai Patel, Hareshbhai* | 8, 9 |
| BK Amin High School | Manund | 2734-275232 | Ishwarbhai Patel | Varshaben Patel, Dirubhai Patel | 8A, 8B, 9B |
| C.A. Panchal JayBharti Vidalaya | Sander | 2734-287723 | Jagubhai Patel | Vipulbhai Modi, Yogishbhai Patel | 8B, 9A, 9B |
| Ramji Vidyalaya | Islampur | 2734-280444 | Chandubhai Patel | Vinodbhai Patel, Ashokbhai* | 8, 9 |

*A new teacher that began teaching in January (3 months into the Hands-on Science pilot project).

# Appendix 2: Hands-on science pilot project lesson plans

*(Taught between November 2003 and July 2004. Designed for 35-40 min class periods.)*

## Origin of species and evolution

***Standard****:* 8

***Topic****:* Theories on the origin of species.

***Objective:*** To probe students to start thinking about their own beliefs about the origin of humankind.

***Teaching approach(es):*** group work.

***Background:***

- People of all countries, religions and cultures have tried to understand the origin of humankind.
- Two major streams of thought: a single creation event and evolution.
- Evolution→ the ancient ancestors of humans are simple organisms. The simplest of organisms have structures or organs that provide the same purpose in humans.
- Creation event→ a higher being created all living creatures separately (i.e., Christian thought).
- What does Hinduism say about origin of species?
- What are students' beliefs about origin of species?

***In groups:***

- Each group is given a pair of organisms: human and a different species (e.g., human and monkey, human and fish, human and dog, etc.).
- Students must compare and contrast the pair. They should consider at least the following aspects: 1) How does the animal take in breath? 2) How does the animal reproduce? and 3) What homologous structures do the two animals share?

***Re-group:*** Each group shares their comparisons and contrasts. Do the results give us a clearer understanding of origin of species? There is no right or wrong answer, but all students should realize the importance of determining their own beliefs about how humankind came to be.

***Results:*** I was surprised that students did not have their own opinions on how humans came into existence. I assumed that because this is a very religious community, that they would at least know what Hinduism had to say about the subject. Because these were all new ideas, I emphasized to students that they should start the thought process for themselves; ask parents and teachers what their beliefs are; find out what their religion says; gain a clearer understanding of what evidence science has to offer; and then, finally come to their own conclusions about the origin of human kind. I thought the mini exercise on comparing human to another animal would be simple for students. I gave some comparisons as examples, but often, students still had trouble doing the problem independently in groups.[11]

[11] In retrospect, it's surprising that I didn't emphasize that evolution is a fact based on science. Perhaps I was trying to see if students would arise at the conclusion themselves. If I were to lead such a lesson again, I may have allowed for lots of exploratory thoughts again, but I would have been sure to end the lesson emphatically stating the scientific basis of evolution.

## *Natural selection and selective breeding of plants and animals*

***Standard:*** 8

***Topic:*** Plant breeding.

***Objective:*** To show students what technique farmers use to produce desirable crops.

***Teaching approach(es):*** Group work.

***Background:***

- Re-cap of evolution (from *Origin of species and evolution* lesson).
- Charles Darwin contributed a lot of ideas about origin of species. He worked on gaining a better understanding of why some species die off quickly, while others survive.
- Darwin observed that all living organisms have the capacity to reproduce in large numbers, but all offspring do not survive because they do not have enough living space, food, or they are eaten by predators.
- Animals that survive are ones that are able to compete and cope with adverse conditions.
- Darwin also observed that members within a species vary and variations are favorable because they give them the ability to survive (provide an example).
- The theory of natural selection states that individuals with variations which are favorable to their environment are selected by nature and allowed to live. The fittest organisms survive.
- Selective breeding: man interferes in the breeding of animals and plants and selects for favorable characteristics.

***In groups:***

1) List crops that are grown in your community.
2) List what are considered to be the favorable traits of each crop.

***Re-group:***

- Each group shares, from their list, one crop and its favorable traits.
- What is selective breeding? How can we use it to produce favorable crops?
- *Further learning:* Are there any characteristics of a buffalo that make it produce more or better tasting milk? How could you breed buffaloes that have such traits? Twist: males do not produce milk, so how would you pick the father?

***Results:*** I think the topic of the lesson was very appropriate since these students come from a farming community and students are experts on the practicalities of farming. I think it is necessary and useful to give students problems that are directly relevant to their community. The students often had difficulty in coming up with favorable crop traits. They would give answers such as give the plant more water or use better soil, not understanding that I was asking for traits that are inherent to the crop.

## *Conservation of natural resources*

***Standard:*** 8

***Topic:*** Conservation of natural resources.

***Objective:*** To prompt students to think about what resources they use in their lives and how to ensure that these resources do not run out.

***Teaching approach(es):*** group work.

***Background:***

- Resource = material necessary for life.
- Natural resource = such materials which are obtained from nature (e.g., air, water, plants, animals, minerals, and sunlight).
- Renewable vs. non-renewable natural resources.

***In groups:***

- What resources does this community need to survive? For example, think about what is necessary for a good farm, for transportation, for paper, for cooking, or for building a house?
- Categorize resources by whether they are renewable or nonrenewable and whether there is an abundant supply or not.
- If the supply of the resource is low, what can we do to make sure it does not completely run out?

***Results:***

I would rate this lesson plan as mediocre. I was not especially creative in designing it, and thus, I do not think it was particularly exciting for the students. Students had difficulty in trying to apply the problem to their own village lifestyle. Many resources they came up with were ones I had already given to them as examples. Students also had trouble classifying resources as renewable or non-renewable.

## *The importance of asking questions*

***Standard:*** 8 and 9

***Topic:*** Asking questions

***Objective*****:** To give students an understanding of why asking questions is integral to the learning process.

***Teaching approach(es):*** Discussion and interactive activity.

***Discussion:***

- Why is asking questions essential for learning in and out of the classroom?
- We can ask questions when we do not understand something and also when we want someone to expound upon a topic.

- When scientists do research, the first thing they start with is a question, and then according to the question, they run experiments.
- Emphasize that curiosity and taking an interest in all subjects, go hand-in-hand with asking questions.
- Why do students not ask questions?

***Exercise:*** Tell a short story in Gujarati about a small gam where a number of people are falling sick, and some are even dying. A number of surrounding circumstances are given, but it is not clear why people are falling ill. The students' task is to ask as many questions as come to mind about the story. They are to play detective/scientist. Their task is not to deduce what happened, but to instead start the investigative process by asking questions.

What type of questions did students come up with? Was it easy for them to come up with questions? Did they take an interest in the story? In a classroom, they should take the same interest in topics, which would naturally lead to asking more questions.

***Results:*** I actually felt this was one of my most successful lessons thus far. I did it for both $8^{th}$ and $9^{th}$ standard students because it is a general topic that is really applicable for all students. All the students I did this lesson with took a sincere interest in the topic and were quite focused. While I know they will all not go on to ask lots of questions in class, I am confident that they understood the importance of the message and will think twice about speaking up the next time a question comes to mind. This lesson was successful because almost every teacher I worked with understood the significance of the lesson and followed up my 25 minute lesson by re-emphasizing my points and by taking it one-step further with more examples and more ways this topic was relevant to their lives. Exercises like this one are useful because they emphasize points in the learning process.

## Introduction to pollution

***Standard:*** 8

***Topic:*** Basics about pollution.

***Objective:*** To give students an understanding of the various ways humans pollute the environment and the effects of pollution.

***Teaching approach(es):*** group work.

***Background:***

- Pollution = contamination of land, water, or air by discharge of harmful substances.
- Examples of pollution: CFC from refrigerators, disposal of trash, etc.

***In groups:***

- Each group is given one of the following examples of pollution:
    1. Over-use of rickshaws and cars.
    2. Pesticides for farming.
    3. Drainage system in cities (gutters).
    4. Chemical plants' disposal of waste.
    5. Biomedical waste disposal.

- Discuss how pollution is occurring in their example and what the effects are on man and the environment.

***Re-group:*** Each group shares what they discussed. As each example is discussed, teacher should fill in gaps with additional useful information. Discuss the motive for why man pollutes (i.e., it often costs more money to have environmentally-friendly practices). Discuss any other examples of pollution that come to mind.

***Results:*** I think that the topic was very relevant, and it got the basics across about the causes and effects of pollution; however, I do not think it was the most creative or exciting way to get across the topic. It was encouraging to know that a lot of students already had some sort of prior understanding of pollution.

## *Acid Rain*

***Standard:*** 8

***Topic:*** Acid Rain

***Objective:*** To give students an understanding of the causes and effects of acid rain.

***Teaching approach(es):*** group work and laboratory exercise.

***Materials:*** vinegar, chalk, and glass beakers.

***Background:***

- Review discussion on pollution (from *Introduction to pollution* lesson).
- Acid rain is another example of air pollution.
- The main causes of acid rain are $SO_2$ and $NO_x$.
- The majority of these oxides come from electric power generation, which relies on burning fossil fuels like coal; other sources are automobiles and other forms of transportation and industrial processes.
- $SO_2$ and $NO_x$ enter the atmosphere and react with water, oxygen, and other chemicals to form acidic compounds. Sunlight increases the rate of this reaction.
- The result is a mild solution of sulfuric and nitric acid.
- Sulfuric and nitric acid fall back to earth mixed with rain, snow, and fog.
- Effects of acid rain: damage to crops, forests, bodies of water (fish), damage to buildings and statues, other animals' and human health.
- Slow deterioration of building and statues is due to acid rain.
- If the building is made of limestone, it deteriorates more rapidly.
- Acids react chemically with limestone.

***Experimental protocol (to be done in small groups*)**:**

- Each group gets 1/3 glass vinegar (acid rain) and piece of chalk (limestone).
- Add chalk to glass (first predict what will happen).
- Write down observations, and in groups discuss reasons for what may be happening.

***Re-group:*** Talk about the results of the experiment. Discuss possible variations of the experiment and what would be the results in each case.

***Results:*** The students seemed to get the main points quickly. The experiment was very simple, but it was a good exercise in taking the kids through the experimental process: predicting the outcome, learning the procedure, making conclusions, etc. When I asked the kids what the outcome would be if we played with different variables, the students were able to come up with the correct answers, which made me feel confident that they understood the underlying concept. They were excited to be doing the experiment (as simple as it was) on their own in groups, since normally they are used to the teacher doing a single demonstration for the entire class.

## *Earth (part 1)*

***Standard:*** *8*

***Topic:*** Basics about the earth

***Objective:*** To start building a model of the earth. To give students an understanding of its shape and other basic characteristics.

***Teaching approach(es):*** group-work, hands-on activity, and themed lesson.

***Materials:*** flour, water, balloons, newspaper, and a globe.

***Background:***

- How do you get from India to America? Can you walk? Can you take a train?
- What is the shape of the earth?
- What did people believe about the earth's shape in ancient times? People believed earth was flat and that if you went to the edge, you would fall off. Explorers figured out that earth was a sphere when they sailed and kept sailing and ended back up at the same point. This is what is taught in the West. What do students in India learn?
- In a series of themed discussions on the earth, the following are some of the topics that will be covered: how earth is positioned in space relative to sun, why seasons occur, why days are 24 hours long and a year is 365 days, and why America is 12 hours behind India.
- Show a globe, pointing out the locations of different continents and oceans.

***Making a model globe using paper mache:***

- Divide the class up into small groups (each group makes 1 model).
- Inflate balloons. Tear newspaper up into about 2"x 6" strips. Dip the strips into the glue (3 parts water plus 1 part wheat flour), and smoothly layer them on top of the balloons.
- Globes will sit and dry overnight. The following lesson, students will use paints to distinguish continents from oceans.

***Related math problems:***

If students finish early or a lot of them are doing nothing, give them the following problems to figure out:

- Earth's diameter = 12,756.3 km; What is its circumference?
- Earth rotates at speed of 15 degrees/hr; How long will it take to make a full 360 degree rotation? What is the speed of earth's rotation in km/hr? (hint: use the circumference)

***Overall Results:*** This was a very chaotic lesson to run because the students lacked focus and discipline when working in groups and because the activity, itself, was messy. The students had a hard time working together efficiently and following directions. They wanted to jump into the activity before I gave directions, and they did not listen well when I did give instructions. We did not have a chance to work on the math problems at all. Ideally, group work should give all students a chance to participate, but because of limited materials, groups were large, and all group members could not help make the model globe. This left a lot of students not engaged in the hands-on activity.

## Earth (part 2)

***Standard:*** 8

***Topic:*** Continuation of basics about the earth

***Objective:*** To complete a model of earth.

***Teaching approach(es):*** group work, hands-on activity, and themed lesson.

***Materials:*** paint, paint brushes, and a globe.

***In groups:***

- Students look off the globe in order to roughly sketch continent borders.
- Use paint to distinguish land vs. ocean on the globe (still working in the same groups as in *Earth (part 1)* lesson).
- If time permits, complete the basic math problems from *Earth (part 1).*

***Overall Results:*** Every class was different with some completing the entire model, while others spent so much time drawing the continent borders in detail that they did not even start painting. Regardless, the students enjoyed the activity, and the teachers, overall, thought this hands-on activity was good because it allowed students to be creative. Making the model has imprinted in the students' minds the shape of the earth and the general locations of the continents. We again did not have a chance to calculate the math problems. Their importance probably warrants an entire lesson. Similar to *part 1*, this activity was ineffective at engaging all students because an entire group of 5-7 students cannot work at the same time to paint one globe. Ideally, it would have been a more effective activity if there were enough materials for all students to make their own model globe.

## Earth (part 3)

***Standard:*** 8

***Topic:*** Earth's rotation and orbital and related math problems.

***Objective:*** To give students an understanding of earth's rotation and its position in relation to the sun.

***Teaching approach(es):*** Group work and themed lesson.

***Materials:*** A globe.

***Discussion and group work (all math problems to be solved in groups):***

- Problem*:* What is the circumference of earth? Given: diameter = 12,756.3 km.
- Have students act out how the earth moves about in space. One student is the sun and the other is earth.
- Problem*:* How long does it take earth to make a full 360 degree rotation? Given: earth rotates at a speed of 15 degrees/hr.
- Problem*:* What is the speed of earth's rotation in km/hr? (hint: use the circumference)
- Interaction between earth and moon over the years has slowed down earth's rotation. 900 million years ago, there were four-hundred and eighty-one 18-hr days in a year.
- Why is one year 365 days long? Discuss how in actuality, it's 365.26 days. Speed of orbital = 107,000km/hr.
- Again, take 2 students to act out the sun and earth. The front of "earth" has India and the back (180 degrees away) is the US. As they act out the relationship between earth and sun, explain why time zones exist.

***Results:*** I was really surprised by how much difficulty the kids had with the math problems. The students needed more guidance and could not calculate the problems independently in groups. I had multiple classes where even when I plugged in all the numbers for the circumference equation, not one single student calculated the multiplication and division properly. Often times, the students did not know even how to approach the problem. I think acting out the earth and sun's interactions with one another was useful, as many did not even realize that the earth rotates on its own axis. While we emphasized over and over why a day and a year are as long as they are, the students still had trouble remembering the explanations by the end of class.

## Earth (part 4)

***Standard:*** 8

***Topic:*** Seasons.

***Objective:*** To give kids an understanding of how earth's tilt affects seasons.

***Teaching approaches:*** Discussion.

***Materials:*** A globe.

***Discussion:***

- Review—act out earth and sun's relationship to each other and while acting this out, ask students how long it takes earth to make a full rotation and how long it takes earth to orbit sun.
- Locate north and south pole on the globe.

- When we look at the model globe, why is the north pole not directly facing upwards and the south pole not downwards? Earth is tipped at 23 ½ degrees—again reiterate how many degrees are in a circle by drawing it out on the board (this came up when we discussed the speed of earth's rotation in degrees/hour), asking how many degrees there are and showing this 23 ½ degree difference for the axis tilt.
- Are there any beliefs/stories coming from their religious upbringing that explain the changing of the seasons?
- Today, we will talk about the scientific basis for the changing of the seasons.
- North vs. southern hemispheres.
- Because of tilt, sometimes, the north pole is closer to sun and other times the south pole is closer. When north is closer, will it be hotter in the northern or southern hemisphere?
- Seasons occur because of earth's tilt.
- March 21st and Sept 23rd→north and south pole are equidistant from sun and so both hemispheres receive same amount of light. Length of day and night are equal. Sun appears directly over equator.
- June 21st→ north pole is the closest that it can get to sun. Where is it summer and winter?
- Dec 22nd→ south pole is tilted further toward the sun than any other time of year. Where is it summer and winter?
- What countries are near the equator? Are they considered to have warm or cool climates? Why?
- Why is it so cold at the north and south poles?

***Overall Results:*** I think the students by now have it ingrained in their brains that the earth rotates on its own axis and orbits the sun, as we have done the earth-sun demonstration a few times now. A large portion of the students also have a clear understanding of why a day is 24 hrs long and a year 365 days long. I was surprised by how quickly most students picked up on the seasons topic. I did many examples where I put the globe and sun in particular positions and asked them where it would be summer and where it would be winter and why. By the end of the lesson, most students were able to successfully analyze these situations.

## *Introduction to mitosis*

***Standard:*** 9

***Topic:*** Mitosis and its practical application.

***Objective:*** To give students an understanding of the function of mitosis, where it takes place in the body, and practical situations where mitosis occurs.

***Teaching approach(es):*** Group work.

***Background:***

- Every part of the body is made up of cells (skin cells, nerve cells, blood cells, etc.).
- The process of growing new body cells is called mitosis.

- In mitosis, one cell makes two new daughter cells that are identical to the parental cell (draw diagram on board).
- Chromosomes are found in the nucleus of a cell. Chromosomes contain DNA, which is a chemical that contains all the information for the functioning of the body. DNA tells cells how to make proteins. Humans have 23 pairs of chromosomes.
- The most important part of mitosis is that all the chromosomes replicate and divide, so that each new cell receives the same DNA (thus, parental and daughter cells are identical).
- Mitosis occurs in all body cells with a few exceptions (e.g., nerve cells).

***In groups:***

- Students are given different situations and asked to answer the following: Where does mitosis come in to play? What cells will undergo mitosis and why? What would happen if identical daughter cells were not produced?
- Scenarios:
    1) A small child comes too close to the stove, puts his hand in the flame, and burns his arm.
    2) A child falls and scrapes his knee.
    3) A girl gets a hair-cut. One month later, her hair has grown 1cm.
    4) A man cuts his fingernails. Two weeks later, they are long again.
- Think of a new situation where mitosis would occur.

***Re-group:*** All groups share what answers they came up with.

***Results:*** I think this activity gave students an understanding of how mitosis affects their lives. The problem I gave students (analyzing different situations) was very straightforward and factual-based. It would have been more effective to give them a more open-ended problem that encouraged students to think more independently.

## *Stages of mitosis*

***Standard:*** 9

***Topic:*** An overview of the stages of mitosis.

***Objective:*** To give students an understanding of how the chromosomes are behaving at each stage of mitosis

***Teaching approach(es):*** Group work and interactive activity.

***Background:***

- Review the definition of mitosis and its practical implications (from *Introduction to mitosis* lesson).
- In mitosis, all daughter cells are identical to parental cells because each contains the same DNA. How does this occur? What are the stages of mitosis?

***In 5 groups:***

- Each group is given one of the 5 stages of mitosis.
- Students need to read in their textbooks about their own particular stage and write a short summary of it. Each group needs to be prepared to explain their stage to the rest of the class.

***Re-group:***

- Take students to a large open space, or clear the benches from the center of the room.
- Ask students to form pairs. Each member of a pair is a sister chromatid (2 sister chromatids make up a chromosome).
- Outline a large circle with chalk on the floor and call this a large cell.
- Students are to act out all stages of mitosis with each group instructing the "chromosomes" where to move and how to position themselves at each stage.
- How long does mitosis take in a real cell?

***Results:*** In this exercise, I wanted the students to work independently and teach themselves the topic by using their book as a resource; however, the students did not seem to understand what they read because they could not explain their particular stage to the class and had no clue as to how to direct the "chromosomes" when asked to act out mitosis. Basically, I had to direct them myself. By the end of class, I think students had some sort of understanding of the different stages because of the interactive activity. Getting the students to move around and "be" the chromosomes was a more effective way of demonstrating the process, rather than having me draw out the stages on the board. If we had the opportunity to act out mitosis multiple times over a few class periods, the students would have a solid understanding of it.

## *Heredity—genes and physical characteristics*

***Standard:*** 9

***Topic:*** Heredity

***Objective:*** To give students a basic understanding of how physical characteristics are connected to genes.

***Teaching approach(es):*** Discussion and interactive activity.

***Discussion and interactive activity:***

- How many students can roll their tongues? Make note on the board of how many can and cannot.
- Explain what physical characteristics are (e.g., eye color, hair color, height).
- Review cell division and chromosomes from *Basics of mitosis* lesson.
- How many chromosomes are in one cell? What is DNA?
- There are many genes on one chromosome (e.g., genes for eye color, height, etc.). The DNA in all chromosomes put together stretches to 6 feet.
- Count the number of girls and boys in the class. What is the difference between boys and girls at the DNA level?
- Go back to tongue rolling example; this is a heritable trait.
- Take a survey of the class for a host of traits, including: tongue rolling, gender, handedness, hand clasping (which thumb is on top), and hitchhiker's thumb. Place results on the board

and determine the frequency of the traits. Compare class frequencies to known population frequencies (taken from OMIM on-line).

- Re-emphasize that all these traits are thought to have a genetic basis and that the variation in a physical characteristic is due to variations in genes.

***Results:*** This ended up being a fun lesson to teach, as I watched all the students have fun with testing out the various traits. Genes and DNA are difficult concepts even for adults, but the students seemed to get a basic, practical understanding of them through this interactive lesson.

## DNA as the book of life

***Standard:*** 9

***Topic:*** Basics about DNA and its structure.

***Objective:*** To give students a basic understanding of the components and organization of DNA (a continuation of *Heredity—genes and physical characteristics* lesson). To give the students a more complete understanding of how DNA sequence is linked to physical characteristics and diseases.

***Teaching approach(es)*:** Discussion and hands-on activity.

***Materials:*** A, C, T, and G puzzle pieces.

***Discussion and hands-on activity:***

- Review the connection between physical characteristics and genes.
- Double helix structure of DNA; show basic 3-D model—2 strands with rungs (a ladder).
- The 2 strands are not identical.
- DNA is like a book of life with its on language: alphabet is four letters, A, C, T, and G, four nitrogenous bases. All words are 3 letters long. The book is 3 billion letters long.
- Let the students play with the A, C, T, and G puzzle pieces in order to figure out which bases pair together in DNA strands.
- Base pairing rules—adenine always with thymine and guanine always with cytosine. Difference in chemical structure (how the atoms are arranged) is what affects base pairing rules.
- Why do we care about this mix of A's, C's, T's, and G's? What use are they?
- Long stretches of this alphabet, which contain many words, make up a gene.
- A gene always starts with the same "word," ATG.
- Each three letter word codes for an amino acid and amino acids make up proteins. Use puzzle pieces to make a long strand of DNA. Identify the "words" that make up the strand.
- Different variations in physical traits occur because of variations in genes (review from *Heredity—genes and physical characteristics* lesson). The exact variation comes from one or a few letters in each gene differing between people.
- Almost the entire "book" is identical for all people. The small percentage that varies, leads to variation in our physical traits.
- Why are we talking about DNA? How does it relate to our everyday lives? Discuss physical traits again, as well as common genetic diseases.

***Results:*** I actually anticipated this class would be boring and difficult for the students; however, the students seemed to enjoy playing with the base pairs. I tried to underemphasize the hard science (since this is a difficult topic) and keep reminding the students of the practical implications this topic. As for the difficulty of the topic, extending the metaphor of DNA as the book of life worked really well to explain the structure and components of DNA. I think using a metaphor also made students remember the concepts more easily. It was interesting talking with students about the real-life implications of genetics. I talked to the students about my previous research experience where I was searching for genes for diabetes. In this segment of the class, students were more interested and asked more questions about other diseases and their genetic component.

## *How does a camera work?*

***Standard:*** 9

***Topic:*** Basics of camera function.

***Objective:*** To show students how the conceptual learning they did on lenses can translate into practical uses.

***Teaching approach(es):*** Lecture with some discussion.

***Materials:*** Negative and photos of varying quality (blurry, clear, overexposed, underexposed, etc.).

***Lecture/discussion:***
There are 3 parts to a camera—optical element (the lens), chemical element (the film), and mechanical element (the camera body)

*Optical element*

- How does a lens work?
- What happens when light moves from one medium to another? (air versus glass)
- How does a convex lens work? Will the image produced be upright or upside down?
- Angle of light entry changes when you move object closer or further away from lens. Consequently, the location of the image changes.
- Simple demonstration of this concept: Turn off lights. Hold a magnifying glass between lit candle and wall. Move magnifying glass forward and back. If lens is not at the right position, rays will not converge on surface of wall, and image will be blurry.
- When taking a picture, lens moves back and forth to make sure the image falls directly on the surface of film and does not appear blurry.

*Chemical element*

- When image hits film, it makes a chemical record of the pattern of light.
- Film is a plastic strip with light sensitive grains. When light hits these grains, a chemical reaction takes place.
- Developing film→ chemicals used to darken the grains exposed to light.
- Negative produced→ lighter areas appear darker and darker areas appear lighter. In printing, a positive image is produced (show example film and picture to show this contrast).

- It is essential to keep film in the dark until ready to take a picture.

*Mechanical element*

- Camera: a box that lets no light reach the film except through a little door between lens and film.
- For a good picture, need just the right amount of light.
- Two methods for controlling entry of light: adjusting size of aperture and shutter speed.
- Conclusion—review 3 components to a camera.
- Next week we will construct a basic camera (pinhole camera) that will show an image on piece of paper, not film.

***Results:*** I think this was a very successful precursor lesson to building pinhole cameras. The students are obsessed with pictures and cameras. Thus, taking apart this particular technology in detail was appropriate. It was also good for them to see how concepts about light and lenses (topics addressed earlier in their syllabus) can be used for practical purposes. This lesson was more lecture-based than other lessons I have taught because I wanted to give students a sound factual basis before making the pinhole cameras in the next lesson. I tried to make it as interactive as possible by prompting students to apply their previous knowledge on light and lenses wherever possible.

## *Pinhole Camera*

***Standard:*** 9

***Topic:*** Making a pinhole camera (follow-up to *How does a camera work?* lesson).

***Objective:*** To use the pinhole camera experiment to demonstrate how light beams come together to form an image.

***Teaching approach(es):*** laboratory exercise.

***Materials:*** Tin can, hammer, nail, rubber band, masking tape, black construction paper, and wax paper.

***Background:***

- Review how a camera works.
- Introduce the concept of a pinhole camera→ When the camera is pointed at a scene, each point in the scene emits light, which passes through the pinhole. The light beams converge and form an image on the wax paper.

***Experimental procedure:***

1) Punch small hole in center of can's closed end using hammer and nail.
2) Cover open end with wax paper, securing with rubber band.
3) Cut 14 in. square from construction paper.
4) Wrap square around circumference of the can like a sleeve and secure with tape.
5) Leave about 10 in. of the black paper extending from the end of the can with the wax paper.
6) Darken room and point hole in can toward a window.
7) Hold black paper cylinder up to your eyes.

8) An image should form on the wax paper.

***Results:*** This was a very successful lesson. Making the camera was a simple procedure that took little time. This gave students plenty of time to play around with the cameras. The students and teachers both enjoyed and were excited about how the pinhole cameras work. Since I have started teaching, this has been the third 9th standard lesson that I have given that is related to light. By now, the following ideas about light are ingrained in most students' minds: what color rays are absorbed and reflected off objects, how converging lenses work, and the scientific basis of why you cannot see objects in the dark.

## *Respiratory and circulatory systems*

***Standard:*** 9

***Topic:*** The connection between the respiratory and circulatory systems.

***Objective:*** To give students an understanding of how oxygen is taken in, dispersed throughout the body, and used by cells.

***Teaching approach(es):*** Hands-on activities and discussion.

***Materials:*** String and a watch.

***Discussion and hands-on activities:***

- Introduce the basics about the respiratory and circulatory systems.
- In pairs, use string to measure the size of your ribcage. Note differences between size when taking a deep breath in and after letting the air out. What accounts for this size difference?
- What substance is taken in when we breathe in? What is this substance used for?
- How do you feel after running for 20 min? What is taking place in the body?
- Feeling your veins—in pairs, person A clasps hands tightly above B's right elbow. B makes fist with right hand and then bends and straightens arm 4-5 times. What do you see? Why are the veins swollen?
- Veins vs. arteries—Where do they carry blood to and from? What are the relative $CO_2$ and $O_2$ concentrations in each vessel?
- Beat of pulse—calculate pulse (beats/min-wrist). Where else in your body can you find a pulse? When blood from the heart is pushed into arteries, arteries also beat along with heart. This beat is called a pulse.

***Results:*** I was pretty pleased with the success of this lesson. Students had already discussed this topic a couple months ago in their syllabus, but it was obvious that they did not have the clearest understanding of it. Thus, it was good we reviewed it and added more detail with practical examples and activities. Previously, the students also did not understand the connection between the two body systems. By focusing on how oxygen is obtained, circulated, and used in the body, the students saw the connection. For our discussion on arteries and veins, I came up with a useful analogy: oxygen is the passenger, blood is the vehicle, and the blood vessels are the roads.

## *Evolution—focusing on importance of opposable thumb*

***Standard:*** 9

***Topic:*** Development of the opposable thumb in primates.

***Objective:*** To give students an understanding of the necessity of an opposable thumb.

***Teaching approaches:*** Group work and hands-on activity.

***Materials:*** String, chalk, and scissors.

***Background:***

- What is evolution? (A review from 8th standard curriculum)
- Who are primates? What are some primate characteristics?
- The opposable thumb is one unique characteristic of primates.
- What would happen if you did not have thumbs? How would it affect your life?

***In groups:***
One student is the recorder, while the rest of the group tries to accomplish the following tasks with their thumb taped to their hand. The tasks are written on a note card and given to each group.

1. Place a notebook on the bench.
2. Open the notebook and turn one page.
3. Write your name in the notebook with a pen.
4. Pick up a piece of chalk and write name on the board.
5. Cut a circle out of a piece of paper using scissors.
6. Unbutton one shirt button and button it back up. (Boys)
7. Take a bangle off and put it back on. (Girls)
8. Tie a knot in a piece of string.

The recorder for each activity writes the answers to the following questions (these are written on the board):

- Is it possible to accomplish this task?
- Is the task more difficult without the use of the opposable thumb?
- How did you have to change your usual technique for carrying out the task?

***Regroup*:** Ask students what was the purpose of the activity? What was the most difficult task to accomplish? Would organisms without opposable thumbs be able to carry out these tasks on a regular basis?

***Results:*** This activity was a fun one, and most of the students got the point that having a thumb allows primates to accomplish tasks more efficiently. This topic was also appropriate because it re-introduced the concept of evolution to them. Evolution was a part of their 8th standard curriculum, but most had forgotten the meaning of the concept.

# Introduction to the atom

***Standard:*** 9th

***Topic:*** parts of an atom

***Objective:*** To give students an understanding of where atoms come into everyday life and to show students how the different atomic components are arranged and how they behave.

***Teaching Approaches:*** Discussion and interactive activity.

***Background:***

- Where are atoms in our everyday life? Are there atoms in my body? Hair? The dirt? Trees? Etc. Are thoughts made up of atoms?
- What are the components of an atom and how are they arranged within the atom?
- Explain atom vs. element. How does one element differ from another?
- Discuss charge of different components and count of each component in an atom.

***Activity:***

- In an open space, use chalk to draw a series of concentric circles to represent an atom's nucleus and electron orbitals.
- Assign some students to be protons, others to be electrons, and another group to be neutrons.
- Starting with the simplest element, Hydrogen, have the various atomic components arrange themselves in the "atom."
- Do the above for a number of other elements, as time permits.
- As the activity is going on, discuss the maximum number of electrons each orbital can hold, electrons' behavior within an orbital (they are high energy and constantly moving around within the orbital; thus their exact position at any given time cannot be determined), atomic mass, and atomic number.

***Results:*** This activity turned out to be quite successful. Most of the classes had been working on this introductory chemistry unit for 1-2 weeks with their classroom teacher before I did this lesson; however, I was amazed that the students were still quite unclear as to where atoms are found in everyday life (i.e., they did not know the human body, the ground, etc. is made of atoms). The students enjoyed the participatory, visual demonstration.

# Appendix 3: Additional sessions for science teacher training programs

***Session 1: Assessing classroom structures***
Goal: To give attendees practice in analyzing teaching styles and methods.
Approximate time: 1hr 30min
Session structure:

1) Session leaders introduce the concept of a hands-on based science curriculum. Explain the importance of activity-based learning and why it is beneficial for students. Give examples of activities that can be used in the classroom to demonstrate particular scientific concepts. (20 minutes)
2) Provide multiple classroom scenarios that are structured in different manners (i.e., lecture-based learning, small-group format, and laboratory exercises). These can be presented as videotapes of actual classroom lessons and/or as mini-skits acted out by session leaders. (20 minutes)
3) Break up into groups (5 attendees/group). In groups, they should compare and contrast the various scenarios, paying attention to the classroom environment, the interaction between teacher and student, and students' level of interest. They should formulate a list of teaching techniques that were effective and not effective in each scenario. (20 minutes)
4) All attendees re-group and share their assessments of the scenarios. (30 minutes)

***Session 2: Designing hands-on science lessons***
Goal: To prompt key resources to start the process of creating hands-on activities on their own. To encourage key resources to think critically about how to effectively design and teach such activities.
Approximate time: 1hr 30min

1) Break up into groups (5 key resources/group). Each group is given a different science topic from the existing $8^{th}$ or $9^{th}$ standard science curriculum. Each group's task is to design a 40 minute lesson plan on that topic, keeping in mind the following guidelines:
    - The lesson should be interactive, involving all students in the classroom.
    - Minimal time should be used for lecturing.
    - The activity should be reasonably enjoyable for the students, while at the same time demonstrating a scientific principle.
    - There must be some element that attempts to test students' comprehension of the concept.
    - If supplies are needed, the activity should require only inexpensive, locally-available materials.

   Teachers should include their lesson objective(s) and step-by-step method of implementation. (60 minutes)
2) All the key resources re-group and share their lesson designs with other groups. Other groups are to respond with comments about the effectiveness of the lesson design and advice on how to improve the lessons. Other groups should also indicate how they think students would respond to each lesson and why. (30 minutes)

***Session 3: Teaching interactive lessons***

Goal: To give teachers a chance to implement what they have learned in *Sessions 1* and *2*.
Approximate time: 1hr 35min

1) Each group is assigned a scientific concept (different from their topic from *Session 2*). Each member's task is to design a simple activity (5-10 minutes long) that he/she would use to teach the topic. (20 minutes)
2) Each member should teach the activity to rest of the group. After all group members have taken their turn at teaching, they should develop a list of characteristics that made a particular activity effective. They should also list any problems they encountered in teaching and what can be done to avoid them. (45 minutes)
3) All the attendees re-group and share the results of their lessons. (30 minutes)