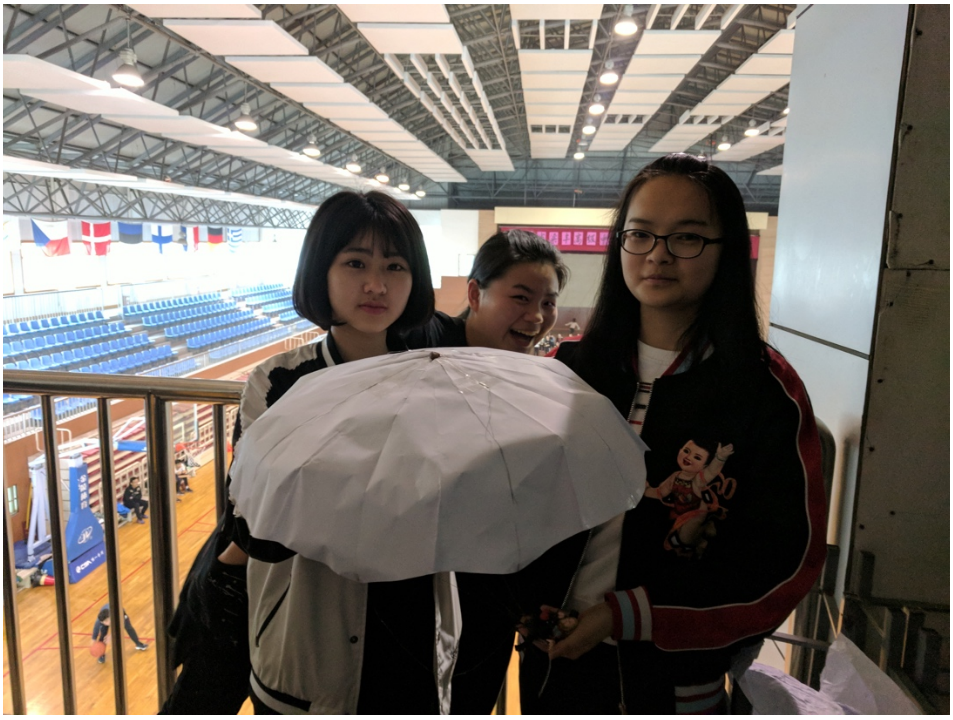
Teaching Science through designing experiment-based projects

When a teacher combines lectures style of education with hands-on experience learning, magical things can happen for students. This is a lesson I have come to learn while teaching my physics classes. In China, teachers strive for a student to accept the information from textbooks and from our class lectures, with the goal of the students using the information to pass the required exams. Although this method of learning has been successful for Chinese students for many centuries, the western model of project-based learning and group learning has also been successful in their education models. By combining the two methods of education, I have discovered that my students learn much more material, are engaged in my classes, and are more effective in their thinking and understanding. The following is a story about my "ah-ha!" moment of this realization.



One semester ago, a dozen American high school students varying grades from 9 to 11, coming from our sister school Craig High School for a visit, sat in my grade 10 physics class since they just temporarily changed their schedule. And I had been just noticed nearly 3 hours ago.

What would I do? I asked myself.

Beyond that, I had already prepared to deliver a standard lecture in class. We had been reviewing questions from the textbook and the homework about the material covered. We had just finished learning the basic concept of equilibrium. It found out that they worked well on balancing forces and dealing with simple questions by using the law of leverage. My students seemed to understand the concept of balancing forces and understanding the simple questions from the textbook regarding the law of leverage. However, the students seemed to struggle with understanding of one of the textbook examples. The problem in the textbook dealt with hanging loads in the correct position so that the tension of the three ropes would be equal. I suspected that the students were having difficulty with this concept due to the textbooks two-dimensional explanation to a three-dimensional problem. Another possible reason the students struggled with this problem was that they could not visualize the solution. I was confident that my students could “plug” the numbers into the formula and figure out the answers, but I was less confident that they truly understood the real-life implications that was being taught to them.

The difficulties lead me to think:

- How could I lead an effective learning among those kids of different grades?
- How could I conduct an effective teaching without changing the original teaching objectives?

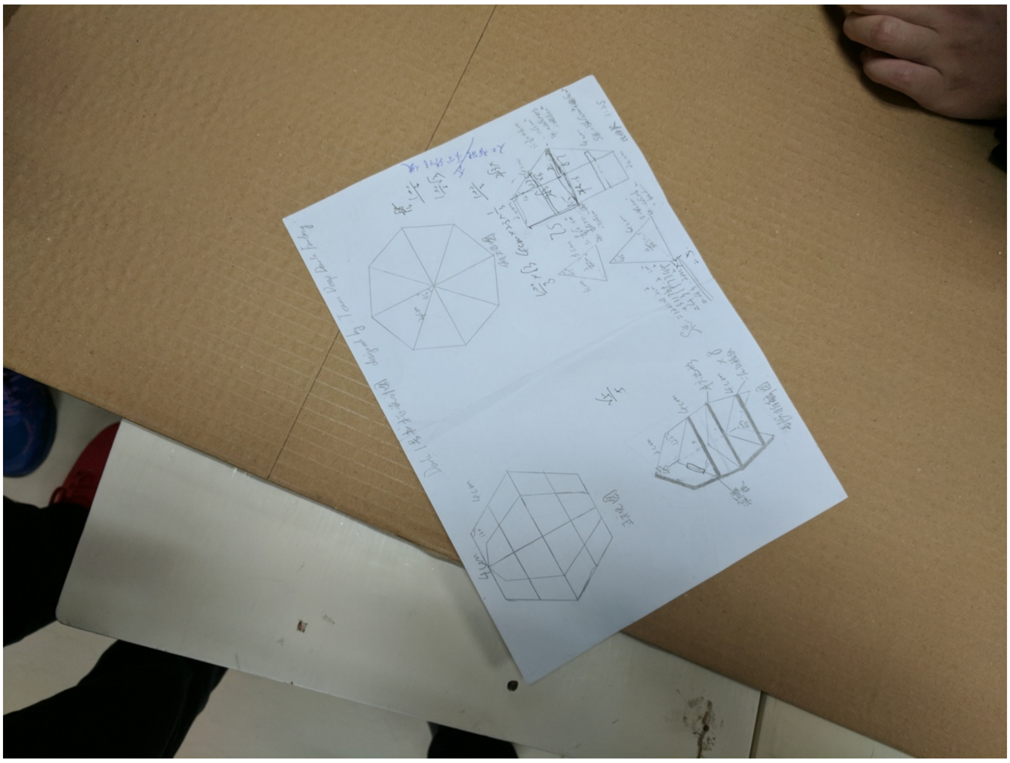
What would I do? I asked myself again.

Have them do the simple load-on-beam experiment sounds like a safe idea. After all, there has already been a clear statement of the experiment processes in their textbook.

It seems like a win-win solution. This experiment is less demanding on student than theory lessons. Like for me, it’s easy to agree that whether they utilize the force scale correctly or made out a correct data analysis than to determine their learning stage of Bloom’s Taxonomy.

So, what? Show them instructions, let them do the work, assume that understanding will emerge automatically from the experiment itself?

Would the student transfer the acquisition of this experiment to a new problem? Would the students only do the bare minimum, or would they stay engaged and take the experiment beyond the constraints of the expectations?



Once I was determined to continue with this concept of teaching, I had another problem to overcome. If I hastened the design of an experiment class, the following gaps might occur for the students.

- There is the gap between science class and the real world that would have to be bridged. The method of scientific inquiry seems to be awakened more in the laboratory but less in students' daily life.
- Then we will have to address the gap between recognizing the value of existing knowledge and creating your own knowledge. Would the students be trapped by their current knowledge and have extreme difficult developing their own, new knowledge from things they learned from the experiment? What would happen if they made a self-discover that contradicted what they had been previously taught? Could they accept something new, that they discovered on their own, versus a fact that can only be verified as true by a teacher or textbook?
- Another gap to be conquered is the gap of passive acceptance and active exploration. Once the initial excitement of entering a lab or new environment (outdoor experimentation) depletes among the students, would the students lose interest in the experiment and find the process boring?

A big question to ask is, "what the expectations of learning for the students are while doing the experiments?" The students should:

- Observe
- Measure and understand the process of measurement
- Determine variable and the processes those variables have on the experiment
- Calculate error propagation
- Make hypothesis and determine solutions/answers
- Create calculations, graphs, and charts to show the progress of the experiment
- Utilize the information gained and compare/contrast the information to what is already known
- Infer conclusions and proposals while making a formal reporting of the experiment results

To this end, we take students into well-equipped labs. However, before one bares arms, he should have a reason to shoot for his own. Human beings have a desire to explore the world. We love to poke and prod things to see how things operate in the world. As long as people have a reason and a need for exploration, we will continue to experiment to discover truths and information. Students are human too. As such, their thirst for exploration and experimentation will easily drive them to pursue knowledge that may not be available to them in their textbooks, but only through various scientific experimentation.

All of this brings me back to my personal experience of implementing experimentation into my lesson plans. My ultimate goal is to allow the students an opportunity to discover or apply the laws of science for themselves.

During my lecture, I introduced the students to the Chinese fable of three monks. It says one boy is a boy, two boy half a boy, three boy no boy. One monk fetches water to drink. Two monks carry water together. Three monks are together. Each of them counts on the rest two to carry water. So, there is no water to drink.

Once I have told the students the story, I divided them into groups. I pose the question to the students, "Can we find a solution in which all three monks can carry the water to the temple from the river?" . In their groups, the students deliberate possible solutions to the problem for five minutes. Some of the solutions they proposed were:

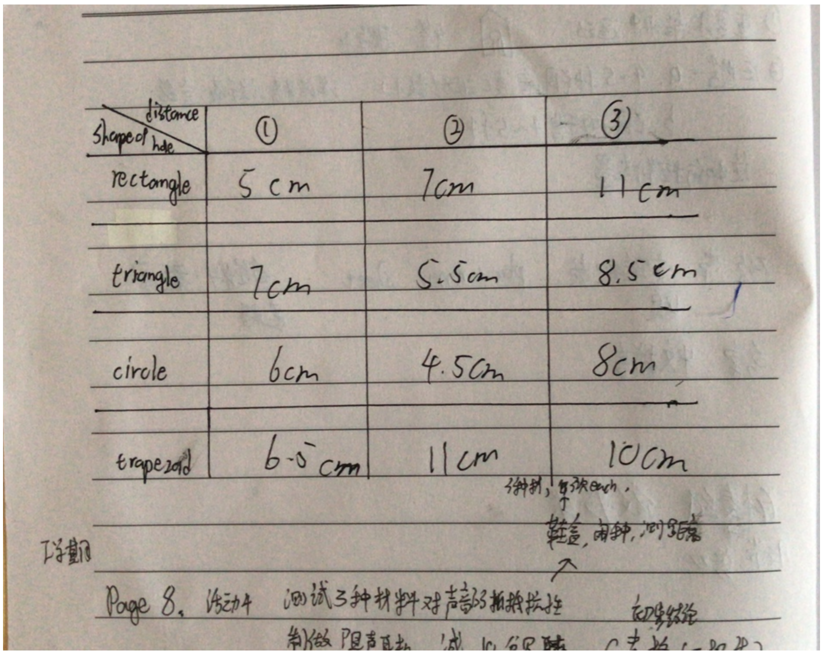
- The monks should develop a schedule and work in pairs to deliver water to the temple.
- Another group suggested that the monks should agree on the concept of collectivism and work through that process.
- The third group believed that the monks could build a water supply system that would deliver water from the river to the temple, without having to manually haul the water.

All of these were insightful solutions, but they did not lead to the experiment I intended. As the teacher, I asked them to consider my idea so that we could conduct an experiment. I posed the question to the students. "Can we just design a shoulder pole that would allow the three monks to carry the water at the same time that also gave equal load weight to each monk?" Now that I had them back on the path I wanted them on, they broke into their groups again. They soon began discussing the knowledge we had discussed in previous lessons. Newton's first law was proposed, thus having each monk carry one-third of the weight load. From this discussion, we soon began considering the law of leverage as part of the solution.

After the group discussion, I handed out the prepared materials to each group. They each received a blank poster paper, water color pens, three force scales, string, some pairs of chopsticks, and some suspension weights. The poster paper and water color pens were used to sketch their ideas and draw a blueprint of their designs. The other materials were used to experiment their ideas with. I turned them loose to begin finding a viable solution to the problem. My responsibility was to be an observer and advisor. As I walked around the groups, making myself available for help, I was pleasantly surprised at how well the student engaged themselves into the process. Just as I might begin to show a group a problem with their design, one of their group members beat me to it and offered a solution to the problem. The group were off and running, while I stood back and let them blaze their own paths of discovery.

If they have not yet learned a terminology with clear definition to express their idea, they would develop their own vocabulary so that team communication would remain intact. I once heard the phrase "center of the forces". I was not quite sure what they were referring to, but it seemed that they were circling around the concept "center of mass", which was actually the topic of our next class. Another group decided to experiment with a triangular design and hang the load from the center of the triangle. I asked them why they thought it would work. They replied me a simple world "symmetry". You see, what a simple and powerful ideal it is! During the actual implementation of their idea they soon discovered there was at least one problem with their design. It is hard to connect two sticks by only using strings to hold a 60 degrees angle. Back to the drawing board for them.

Eventually the solution was developed when one team who made the triangle contraption, teamed up with another team who had developed a cross patterned rigging. The real success was not that the teams solved the problem. The true success was the pride and joy the student gained from the process. The students were so proud to post their blueprints on the wall. They each gleefully signed the blueprint, claiming the solution as their own team success. The final jubilation came when they got to share and demonstrate their final results to their other classmates.



distance / shape of hole	①	②	③
rectangle	5 cm	7cm	11 cm
triangle	7cm	5.5cm	8.5 cm
circle	6cm	4.5cm	8cm
trapezoid	6.5 cm	11cm	10cm

While my students learned a great lesson through experimentation, I too learned some things.

- I learned that through experimentation, the students get to stimulate their active thinking, therefore enhancing the knowledge they obtained from the textbook and class lectures.
- Once free from the linear learning route, students will take it upon themselves to construct their own knowledge, even developing their own vocabulary in the exploration. Students do tend to walk their own walk.
- Peer learning is much more effective in class than simply the authority of the teacher.
- For students, it is a far more exciting learning experience to try and ultimately realize their own ideas than to work out an exercise problem from a worksheet or textbook.

In this sense, I achieved the real win-win solution.

Of course, I cannot take credit for this type of learning model. Last year, I was able to encourage our school to become an ASDAN center. ASDAN is an extracurricular activities program for students to experience various topics and learn from experimentation within their chosen subject. My first ASDAN program was a science course. Unfamiliar with ASDAN and the benefits of learning it provides to students, I was surprised. Instead of linear content learning, the course was divided into six modules which the student gets to choose for themselves to complete. The teacher of the course is not there to teach information, but to act as an advisor and help guide the students and keep them moving forward in their modules. More importantly, the students are required to obtain "soft skills" that leads to life-long learning. They are exposed to communication skills, use of information technology, mathematics, teamwork, and recordkeeping. Through ASDAN, and ultimately any project-based lesson, lessons are learned through open-ended questions with undefined boundaries, while showing students the real life practical uses of the knowledge gained.

From my ASDAN experience, I was inspired to integrate the ASDAN learning model into my regular physics class. This year, we have carried out some of the following experiments:

- To study apparent weight, we recorded the change in weight on a bathroom scale in a moving elevator.

- To see polarization of light., we developed our own 3-D glasses.
- To understand fluid dynamic, we constructed our own parachutes from paper to measure terminal velocity
- In the near future we will do experiments with an egg drop, orienteering, and perhaps make an air pressured cannon.
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As teachers, we are never really the designers of the students learning path. Teachers should develop learning environments for students. We should be guides and advisors as the students discover the necessary information. This does not mean that we give up on lesson plans and in-class lectures. These too are vital to the learning process of the students. By adding experimentation, it reinforces those lessons and gives students another perspective of learning the material.

When designing these experiments, I insist on following these rules:

- The experiment should be based on real-life issues with fuzzy boundaries that motivates students to make mistakes and find successes.
- Develop probing and open-ended questions that engage students into deep, critical thinking.
- Establish clear criteria of expectations for the students.
- Students must provide sources and proof of evidence through the use of portfolios, journals, notes, and other forms of recordkeeping.
- Group work is required so that everyone learns from their peers.
- The students do all the work and develop the methods to test their understanding of the target information meant to be learned by the teacher.
- Inquiring questions that will eventually lead them onto the next stage of learning.

There are many types of this kind of learning available. They are known by many names, such as ASDAN short courses, PBL, ABL, STM. Regardless of what you call it or what differences each program may contain, the end result is what we all are striving for. The magical moment when you see the figurative light bulb come on over the student’ s head and the gleaming sense of satisfaction and accomplishment that the student will show due to their successes, is what all this is about. In the end, both student and teacher can revel in the discoveries that they both share. The old way of the sage on stage replaced with the teacher and student co- opting together for the sake of learning. When that happens, both are in a win-win situation.