Preamble

In a grade 9 academic classroom setting I made a few assumptions based on prior experience - 1) students generally are well adept at information retrieval and have had some exposure to science through the grade 7/8 curriculum and 2) all students are curious by nature. With that in mind I wanted to foster that curiosity but focus it through the scientific method.

Discovery learning is by and large a jargon term that exists in a perfect world with unlimited time and resources, outside of the realm of marks, report cards and the dreaded school bell. In practice, restrictions such as safety, materials, classroom layout and direct instructions of curriculum expectations severely limit the time it takes to truly facilitate discovery learning a la Miss Frizzle's class. The few times I have ventured off the beaten path, deviated from my linear unit plans and allowed a lab or discussion or activity to stretch several days beyond my pre-determined amount of time, I found that it was usually well worth the stress or lost expectations because the students ended up a) enjoying the activity, b) engaging it fully and c) gaining a deeper understanding of the concepts involved.

With that in mind I decided to throw caution to the wind and approach my grade 9 academic SNC1D1 class with a holistic approach instead of my expectations checklist style approach that I'd been using for much of my career. I decided to not let units and expectations guide my lesson planning but instead design back from my ideal goal of grade 9: producing students capable of both designing and performing scientific inquiry indecently and of reaching conclusions based on solid, factual arguments.

My motivations derived from having many students able to regurgitate facts and follow procedures but couldn't design a proper experiment or properly analyze results - the very foundation of science. What good is a curriculum that produces student who know about atomic theory or electrical circuits but can't design experiments to further scientific understanding? I would prefer to miss some specific expectations but have students who truly understand how and why the scientific method is such a powerful and transcendent way of thinking.

Connecting Through Concepts in SNC1D1

In a discussion with a colleague who was implementing "sprialling" a planning concept used by our math department in which units were not taught in their entirety but instead cycled a week at a time. In his model, he was concerned with teaching unit 1 in September and by the exam his "review" was basically re-teaching the unit in a day or two because the students hadn't seen nor used the content or concepts in many weeks. I liked this in theory but when I began to plan it seemed that while in theory the students would retain the information for longer periods of time they wouldn't necessarily internalize the foundational understanding of scientific inquiry.

In my model which I dubbed "connecting through concepts," I actually dissolved the unit boundaries in SNC1D1 and instead tried to follow a thread of similar concepts instead of a similar discipline. The idea being, if students realized that scientific disciplines apply the exact same principles to different situations then, perhaps, they would internalize the concepts instead of the knowledge and be better equipped to tackle unfamiliar problems. Theoretically both approaches should minimize the need re-teach topics because students would be continually reviewing topics from each unit throughout the entire semester, but in my approach students should become more scientifically literate because the expectations were simply a means to an end (scientific literacy) rather than knowledge to be memorize and regurgitated.

I have briefly outline my planning structure but this catalyst isn't meant to be an activity or tool to be implemented but instead provide insight on a new approach. I didn't make any new activities specifically for this catalyst (although I did modify a Perimeter Institute activity during this semester that was amazing!!) but instead used my materials in a new way. The other major change that implemented was drastically reducing my scaffolding and direct instruction and, where appropriate, allowed my students to create their own methodologies and became more of a facilitator. My classroom had a lot more commotion and discussion but ultimately I feel even my weaker students came away with a deeper scientific literacy than would otherwise have been possible. I'll explain a little more what I mean below.

Sample Planning Structure

1. ***Safety in the Science Lab***
    1.1. We always start with safety anyway so instead of getting through it to get on to the "real" science I approached this as the foundation of all scientific inquiry - **exploring the world safely** so we would be around to share this information. For example, instead of simply showing my laboratory equipment handout on the projector and having the students fill in the blanks as a class, I instead gave them the handout and said go find out where each item is located, its name, try to guess what it is used for and think of anything that might be dangerous when using that piece of equipment. The result was two-fold. 1) students not only knew the names, they knew where to find it and (more importantly for me) where to put it back! and 2) they were thinking about using it, not trying to remember what it was called!
    1.2. We also did **WHMIS and a safety** quiz but I'm simply outlining the pertinent points for this catalyst. Don't make an all new course, take an all new approach with what you've already got.

    The ***concept*** here is safety is our most important consideration!

2. ***Scientists must using equipment safety and accurately***
    2.1. After safety I usually dive into chemistry and we don't actually use anything for a couple of weeks. When planning I thought this is ridiculous. They're excited to use equipment and do experiments so why not harness that enthusiasm. This time we watched the Bunsen Burner safety video and then we all got up and practiced using them. We did the same by practicing measuring with scales, triple-beam balances and graduated cylinders.

    Instead of handing out prescribed procedures I would usually pose a question like "**Does 10mL of water have the same mass when measured in a different graduated cylinders?**" Then I let the students solve the problem in groups of 3-4. It provided discussion points like sources of error, the importance of multiple trials, averages, the importance of recording units, etc. It taught the students how to properly Tare but also that subtracting the masses was a better method in case another grouped tared the scale while you were doing something else.

    The main ***concept*** here is that if the data isn't accurate it isn't useful for anything.

3. ***Scientists analyze their data to find patterns or make comparisons***
    3.1. I redid my **density lab** a few semesters ago and made two separate baggies of materials. In one baggie are 4-5 regular shaped objects (marbles, hot glue gun sticks, a small cube of aluminum and a small cube of iron (both painted brown), etc.) and one irregular object - a smooth rock. I presented the activity without ever saying the word density. I merely told them we were measuring again. I asked them to create an observations chart with four columns - item, mass, volume and m/V. I told them to find the mass and the volume and then calculate the ratio of mass to

Volume. Then I projected a formula sheet with all of the mathematical formulas for volumes of regular shaped solids and let them go to it. It was awesome to hear comments like “make sure [the scale] is in grams” and “we better measure it twice just to be sure.” This was like week two and already I could see and hear positive reinforcement for what I was doing! Many groups came to me that period with the rock and asked how to calculate it’s volume. I merely said that they didn’t have to calculate it, maybe they could measure it. Several students felt I brushed them off but sure enough some students dropped it into a graduated cylinder and subtracted the difference in initial and final volumes. Without me, this idea spread quickly throughout other groups.

The next day they repeated their exploration using a baggie of 4-5 irregular shaped objects. This time I showed them the overflow canisters and away they went. To a group the experiment went much smoother and quicker than it ever had with my well polished, clearly typed worksheets/procedural labs.

I posed a few discussion questions like “were the blocks made of the same metal?” and let them complete the questions.

When we took up our findings, I explained that proper experimentation was important but if we didn’t ***communicate*** our results effectively it wasn’t useful. I demonstrated how to best record our data to include units and how to properly (GRASS method) record their calculations. I them told them that what they had done was find the *density* of these objects but even before I had done so every group already had a strong understanding that density was merely a description of how much stuff was in a certain amount of space.

3.2. We continued our theme of safety and equipment to try and find the **hottest part of a Bunsen burner flame**. We discussed how to safely approach the question and what tools we should use. Students came up with their own tables to record data and off they went. Afterwards I had students **graph** their data and we were able refine their technique and also bring in the idea of **analyzing** the data we collect.

3.3. Everything had been chemistry oriented so far but I thought that instead of continuing the theme of chemistry, I wanted to instead continue the theme of experimentation and analysis. My link was **graphical analysis**. I mentioned that scientists often use graphing as a means to analyze data and look for trends or to present their findings in an accessible manner. I gave the students a homework assignment from the biology unit where they could create a bar graph instead of the line graphs we had done. From that we moved on to a **simulation of Lynx-Hare predation**. Students’ followed some simple instructions to simulate a carrying capacity experiment. Interestingly, they way it was set up the population has to crash and provides a good platform to discuss why.

3.4. We followed it up with another biology assignment, this time a Gizmo from explorelearning.com where students could collect data digitally and determine the relationship between water temperature and dissolved oxygen and how this affects fish populations. We were able to look at eutrophication from our findings and explore human impacts on local ecosystems. This was particularly relevant for us because we are located between Lake Ontario and Lake Erie and could then discuss why one lake is more prone to eutrophication than the other.

3.5. Perhaps my favourite exploration of the year came next. I didn’t tell the students we were going to explore a space concept, instead I told them that sometimes scientists harness, or even invent, new technologies that help them investigate safer and faster as well as probe new frontiers. I had them all download **Google’s Science Journal** software on their smart phones. I let them play with the sensors -

light sensors, sound sensors and motion sensors. Then I focused them on the light sensor and used a modified version of Perimeter Institute's exoplanet exploration. Students used styrofoam and/or plastic balls on the end of bamboo skewers to take real-time plots of luminosity. I asked guiding questions like explain the differences in the plots of a large ball moving slow vs. a large ball moving fast and then a small ball moving fast vs. a large ball moving slow in order for them to truly translate the graphical data into a real-life situation. Several students on their own correctly predicted that this could be like a planet moving in front of a star and that sparked great curiosity. One student remarked that they noticed a slight difference in the plots when he used a large, translucent plastic "planet" vs. a large, opaque "planet" and reasoned that those differences might be used to identify a gas giant from a terrestrial planet since more light would pass through a gas giants atmosphere since it had a much larger atmosphere. Not a bad conclusion for a grade 9 and without any notes or lectures on the topic!

I decided to roll with their enthusiasm and created an extension activity where I provided them with actual NASA Kepler curves and had them calculate orbital period and the planetary distances from their stars. From this we used some NASA calculations to estimate the size of the planets and when we checked our findings with the accepted NASA values most students were within 5% of the accepted values. Pretty good for grade 9's, some who hadn't completed grade 9 math yet!

3.6. The students really took a shine to space to I stayed with it for a few days but eventually transitioned back to chemistry by exploring the make-up of stars and how atoms are fused and sent into the universe by supernova's. This allowed us to discuss and explore matter and atomic theory.

3.7. After exploring chemistry for a while I again transitioned, this time to electricity by way of the electron and the idea of it moving from one piece of matter to anther. We explored the concept of static electricity and, using safety, discussed lightning and lightning rods and then electrical safety in the home. This connected directly to the concept of current electricity. Returning the the idea of collecting data we built circuits (digitally first, then physically) and were able to measure current, resistance and voltage. We revisited GRASS calculations and graphing to explore Ohm's law and some other electrical calculations (such as Power).

I continued my lessons in this manner but by now I'm sure I have lost many readers with my novel so will move on to the next concept.

4. ***Scientists must communicate their results effectively***

4.1. I enforced this idea throughout the teaching individually via explicit instruction and constructive feedback. I was able to teach proper graphing technique, GRASS method for calculations, the importance of units and clarity in all measurements. I taught them how to thoroughly and concisely write a procedure and how to properly support their conclusions and hypotheses with verifiable facts. My students became quite articulate and thus scientifically literate naturally because it was the language we developed through our many explorations.

I also had students write formal lab reports, a magazine style article on a Canadian scientist and do an oral presentation for space. The more and varied types of communication I could find, the better.

5. ***Scientists revisit and revise their work and findings***

5.1. I wanted a way for the students to revisit their learned and sort their activities into the units so they could easily study for the exam. I had them create a portfolio throughout the semester which included all of their learnings and had them choose their work that emphasized the curriculum expectations. I introduced it a few weeks into the semester and we had work periods scattered throughout the semester. In the “exam review” period, it was the students actively refining and revisiting their learning before submitting their portfolio that served as their studying. They were able to re-do some labs or activities, improve on various items (like lab write-ups or test questions) but in order for them to “qualify” they had to explain what they did wrong and how they were now going to improve.

I felt this was even more valuable than their lab exam because it reinforced the idea that science is fluid and active. Watching and listening to students be able to recognize their own errors or those of their classmates and then explain how and why those errors needed to be corrected was the final confirmation that we had achieved improved scientific literacy.

Epilogue

Empirical data from 30 students in one class for one semester wouldn’t be statistically relevant so I decided not to base success on the usual grades-based markers. Instead I went by student feedback and anecdotal teacher feedback - both my own and that of some colleagues. That being said, even my weakest and perhaps misplaced, students were able to achieve provincial standard on most tasks.

Without question, both the students and teachers involved felt that this approach was a success. The students demonstrated a fundamental understanding of the scientific method and principles in their discussions, writing and oral communication. They were reflective and through in responses to questions and engaged challenges with both an open mind and enthusiasm. They could identify variables, plan their own investigations and reach relevant conclusions based on the evidence presented all while clearly and concisely communicating their viewpoints. Ultimately the goal of my initiative, and that of grade 9 science, is to teach students to be lifelong critical thinkers and that the scientific methodology can be applied inside the science classroom and out. That goal was accomplished in spades.