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8. "THEY CAN'T JUST GOOGLE THE CORRECT ANSWER"

Personalising Science Learning in an Open-Plan Secondary School

CHANGING SCHOOL SCIENCE LEARNING

Natalie, a Year 8 student, responding to a scientist's blogged suggestion that her diagram of her invented spider-bat might need bigger ears (to explain its super-keen hearing and effective survival tactics), blogged back:

> Thanks Dr Dave. I'm glad you like the idea for my Spider-Bat and I will definitely try and fix those ears and I agree that my critter does seem a little defenceless. I will make sure to think about some ways in which my Spider-Bat can avoid being lunch!! Thanks again.

Enhancing students' interest in and learning from school science experiences has remained a challenge for decades in many countries (DeWitt, Osborne, Archer, Dillon, Willis, & Wong, 2013; Duit, 2007; Tytler, 2007). This challenge is variously attributed to: (a) too much didactic teaching that casts students as reluctant bystanders tasked with memorising expert claims, (Duit & Treagust, 1998; Osborne & Dillon, 2008; Lyons, 2006); (b), a disconnect between official science curricula and students' everyday worlds and interests (Aikenhead, 1996); and (c) lack of teacher familiarity with current scientific agendas, discoveries and methods (Chubb, 2014). Proposed and enacted solutions include: changes to the content, purposes and physical settings for learning (Duschl, 2008; Sadler, 2004; Tytler, 2007); integration with other subjects (Freeman, Marginson, & Tytler, 2015); more links with practising scientists (Chubb, 2014); more use of virtual resources (Linn, Davis, & Bell, 2013), and increased explicit focus on opportunities for students to use these and other resources as reasoning tools for learning in this subject (Lehrer & Schuable, 2006; Tytler, Prain, Hubber, & Waldrip, 2013).

In this chapter we briefly review an emerging consensus about quality learning in science as a basis for framing our account of attempts to personalise learning in Year 8 science in one of the BEP schools. We report on the teaching of two 9-week Year 8 science topics, Adaptation, and Science Inquiry), in the second half of 2014. The first topic, called "The Future is Wild", represents a relatively common approach in Australian schools, whereas the second was innovative, not only for this school but for Year 8 science in Australia. We report on each topic to show: (a) how the

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teachers adapted the topics to the open-plan settings and team-teaching; and (b) to indicate the ways in which the teachers sought to enact the goals for quality learning in school science as outlined above. Finally, we present a case study of Year 10 students' reasoning through representations to learn in science from another school.

CHARACTERISING QUALITY IN SCHOOL SCIENCE EDUCATION

Science education researchers now broadly agree that quality learning entails students understanding, enacting and valuing how scientists produce, justify, judge, and share knowledge in this field (Duschl, 2008; Moje, 2007). In this way, as discussed in Chapter 1, quality learning in science needs to engage students deeply, and provide experiences that parallel how scientists produce and disseminate knowledge claims. From this perspective, quality learning entails a complex blend of propositional, procedural, and communicative knowledge and skills as well as dispositional commitment to the value to self and others of learning how this knowledge is made, shared, and revised. In understanding these processes, students learn how to integrate practical inquiry with visual, linguistic, and mathematical modes to reason about causal changes to phenomena, where an engaging, meaningful curriculum motivates them to participate in a sequence of activities and reasoning practices that achieve theses outcomes (Duschl, 2008; Lemke, 2015; Osborne, 2012).

Rather than learning mainly to memorise past expert claims in this field, students also need to have first-hand experience of the challenges and pleasures in making persuasive claims in this subject. When encouraged to explain and justify these claims using different forms of representation, including diagrams, drawings, models, and verbal explanations, students can learn how to reason about scientific topics, advance their content knowledge, and practise the subject-specific ways to represent scientific processes and findings (Ainsworth, Prain, & Tytler, 2011; Liu, Won, & Treagust, 2014; Tytler et al., 2013). As noted by Haste (2004), Lindahl (2007), and Schreiner and Sjoberg (2007), students also need to understand the creative side of scientific reasoning, enabling identity work in this subject to be appealing and valued. By approaching science in this way, students are likely to find science immediately engaging and a source of stimulating challenges. Students are also more likely to view science as meaningful if they can apply scientific methods and findings productively to everyday problems and challenges that relate directly to their lives (Tytler, 2007).

From our perspective (Tytler, Prain, Hubber, & Waldrip, 2013), quality learning in science occurs when students actively construct representational claims, rather than being mainly exposed to canonical representations. Their own constructions focus their attention on the affordances of modes and their uses, productively constrain their thinking, and channel attention to selective key features of phenomena. This engagement with the problem space prepares them to appreciate canonical solutions later introduced by the teacher (Bransford & Schwartz, 1999). Following Vygotsky (1981) and Cazden (1981), we recognise that students' learning capacities are often in advance of their explicit understandings, and therefore they benefit from multiple opportunities to attempt representational tasks before they have achieved full competence in them. Quality learning entails epistemological understandings of the nature of models and representations and their selective purposes. This meta-representational knowledge arises from explicit discussion of representations, and feeds back into their selection and refinement processes.

QUALITY IN PRACTICE

Needless to say, achieving this range of goals and outcomes across 13 years of schooling represents a significant challenge. However, one Year 8 science class at Melaleuca College addressed many of these goals. Drawing on the spatial affordances of a large open-plan area, three teachers planned and team-taught two topics in the second semester of 2014 (*the Future is Wild*, a unit about adaptation, and *Mythbusters*, a practical unit on science inquiry methods) with 70 students using whole-class and group-work approaches. See below for a description of the content and detailed approach taken in each topic. The space was viewed as enabling an enactment of Lave and Wenger's (1991, p. 12) "community of practice" where students were guided to construct knowledge and where their ideas were scrutinised, critiqued, given feedback, refined, and presented to a community of "scientists" that is, their peers. The students were expected to share understandings within small groups, explore and enhance the robustness of their perspectives, and seek to validate, justify, and elaborate their understandings through different representations to their teachers and peers, including blogs and demonstrations. In this way, the teachers sought to avoid a heavily didactic, teacher-dominated process of instruction, and to give students considerable control over choices of topics and the representational resources through which scientific claims were made. Students were also encouraged to connect these choices and topics to their own lives or interests. To enhance the currency and reality of the topics, some interested students were linked with practising scientists in a 'global science' forum. These scientists provided virtual and same-time expert feedback on students' emerging work, questions, and findings by responding to the students' blogs and in follow up Skype conversations (The Global School, 2015). The students were also encouraged to access a variety of virtual resources to support and guide their inquiry, but not to provide a shortcut to ready-made answers. As Bob, one of the teachers noted, the intention of the inquiry process was to set the students achievable new challenges where they could use the internet as a resource or a confirmation of their inquiry findings, but "they can't just Google the correct answer" because of the focus of undertaken inquiries.

The Future is Wild

The Future is Wild unit aimed to cover biological sciences and earth and space sciences content strands of the AusVELS Science curriculum, The students were to consider life on earth at one of three time periods in the future: 5,000,000 years, 100,000,000 years, or 500,000,000 years. Within those time periods they had four choices of environment to study, combining climate and vegetation (hot, cold, desert, forest). For their chosen time period and environment type they had to:

1. describe the physical and adaptive characteristics of three or four actual organisms from the chosen time period;
2. explain why these organisms existed and where they belonged in the food chain;
3. design their own organism, explain how its physical characteristics would allow it to adapt to the chosen environment, how it would interact with other organisms, and where it would fit in the food chain.

The teachers recognised that their student cohort had a spread of tested literacy and numeracy abilities ranging across seven year levels (Years 4–10). The robust

Level E	Represent the life cycle of your organism Represent how your organism interacts with the environment
Level F	Design your organism with structural and behavioural features that helps it survive
Level G	Describe the physical conditions of your organism that help or hinder its survival Describe the geological and extreme weather conditions that have affected your organism's environment
Level H	Classify your organism as if it were alive today Construct a food web that includes your organism and the other organisms present in your ecosystem. Include labels for producers, consumers and decomposers. Describe the seasons in your environment Describe a water cycle in your environment
Level I	Represent and label three kinds of cells in your organism Represent the internal structure of your organism. Describe how it digests and reproduces. Describe the rocks in your environment. How were they formed?
Level J	Describe your animal's systems, with a flow diagram to show how all these work together in your animal Describe the population of your organism. What affects its population? Describe, using plate tectonics, how your environment has changed since today
Level K	Describe the water, carbon, nitrogen and phosphorus cycles in the biosphere of your environment Represent the DNA, genes and chromosomes of your animal Describe how genes are passed on from the parents of your animal to its child. How did your animal evolve? And from what? Describe the process.

Figure 8.1. Curricular guide for the topic of adaptation

curriculum accommodated this spread, providing a positive learning experience for all students, by incorporating curricular goals that spanned seven levels for each topic (see Figure 8.1 for the topic of Adaptation). All students started at level E (Grade 4), but quickly moved over the course of the unit to at least level I, representing expected progress at Year 8 level.

Bob explained that beginning at the same level was appropriate as students had experienced limited, discontinuous exposure to science in primary school making it difficult to diagnose an entry level. Furthermore, "science, unlike mathematics, does not have a clear hierarchy of conceptual understanding". The teachers wanted all students to have a sense of "the big ideas" in science and a larger developmental sense of topics rather than being constrained to thinking about a narrow single-year level perspective on science content. Concepts like the life cycle could be made more or less challenging according to the needs of the students by varying the complexity and familiarity of the organism being studied. With students all beginning at the same stage, they could observe rates of progress among peers, and motivate one another. The additional two levels (J and K) provided extension work to Year 10 level for more able students.

Students watched a general introductory video about adaptation (The Future is Wild, 2015) before choosing their time period. Once selected, they had a further choice of four environments within that period. They watched an initial video on their environment that introduced them to organisms that may exist within the environment, their adaptive characteristics, and interaction with other organisms. They also watched instructional videos at the point when they were ready to learn about a particular aspect of their study. Students were able to bring their own portable devices and use their QR Code Scanners to connect instantly to the videos (QR codes were on the wall for every video) so they could work at their own pace and access the next step when ready. The teachers' intention was that in engaging in rich tasks, students should use a range of technologies to exercise problem-solving ability, creativity and to take responsibility or ownership for their learning. The students uploaded evidence of their understandings on their personal blog sites, with a choice of ways to represent their understandings including posters, photographs, models, drawings, or 3D printing. Fifteen students volunteered to be part of a global science community where they were further enriched by interacting with practising scientists. The scientists' feedback on the student blogs was sometimes followed up by a Skype conversation between scientist and student. Bob found it "mind-blowing to see a marine biologist in Townsville having a genuine non-teacher mediated discussion with a student who was designing a marine animal".

Three teachers (Bob, Steve, and Sue) worked with a combined class of 70 students. The 70-minute lessons usually started with one teacher providing an introduction, orientation and restatement of goals at the start of the lesson. This whole group session might entail introducing a virtual or actual resource to refresh students' memories and enthuse them, setting up the learning goals for the day or week, giving students general feedback on progress, introducing a new section of the topic, or recapping on intended student progress. Students were expected to raise and answer questions at this time.

Following the introduction, students generally moved into small groups to work on their topic, making use of the whole space available, with a range of seating options. Though not stipulated, students found it beneficial to work with others completing the same level. Some students worked at tables in groups of three or four while others worked alone. Some groups worked at computer terminals in the middle of the open-plan space, while others worked outside. Though working collaboratively, students designed their individual organisms, outlined their organism's life-cycle based on life cycles of animals today, created food chains and webs that showed how their organisms interacted with other organisms present in their ecosystem, and identified their animal as consumers, producers and decomposers.

In the course of the lesson, the three teachers circulated to provide feedback and support for individual students, or, where deemed appropriate, provide a practical session or focused discussion for a group of students at a particular level. Bob considered that team-teaching was a "no-brainer" given the open-plan classroom and timetable structure. Team-teaching, according to Bob, allowed teachers to "utilise their particular strengths to better address the diverse needs and interests of their students". Bob tended to work with the more advanced students and conducted workshops for them as they began a new level. For example, he conducted a workshop on habitat and the forces that shape it for eight students beginning level G. He deliberately kept the workshops brief to avoid defaulting to a transmissive style of teaching. Steve assisted those students in the middle range and Sue, a trained primary teacher, worked with the students previously identified as having literacy difficulties. However, this organisation was flexible to respond to student needs, and the teachers were keen for students to understand that they had access to all three teachers during and outside class-time.

Lesson conclusions usually entailed students being gathered together for a short summary session of 10 to 15 minutes. Sometimes teachers praised particular students for working diligently, or the content of an individual student's work was discussed as exemplary. Students were praised for independent problem-solving as well as seeking help, and were also reminded of possible sites for further research. Sometimes the teachers restated the rationale for the multi-year-level curriculum as "the new way we do science at this school". This curriculum was seen as a chance for students to know exactly what level they had achieved or could achieve, to meet year-level expectations by the end of units, and also to progress at their own pace. All three teachers participated in these discussions.

In reviewing this unit, the teachers thought that the use of a 'story shell' to frame the topic was worthwhile. It enabled the curriculum to be differentiated without a perception that students were streamed on ability as all students worked on the same topic but at various levels of complexity. The topic initially "grabbed students' imaginations and fired their creativity". When interviewed about this subject, students expressed a desire for more practical hands-on experiments revealing that this unit challenged their expectations about the format of science lessons. The teachers are considering ways in which aspects of the unit could be explored as experiments in a laboratory environment. Bob was delighted at the quantity of evidence of learning on the student blogs from this unit. However, he was disappointed that students had not taken sufficient advantage of the many options suggested for representing their understandings. Ironically, the students complained that there "was too much drawing" in the unit, yet they had "taken the path of least resistance", to upload photographs of their labelled freehand drawings and writing on their blogs as evidence of their learning. Bob thought this could be addressed by providing visual examples of the options and referring students to previous students' blogs for inspiration.

Mythbusters

The *Mythbusters* unit provided different challenges for teachers and students. The unit presented the students with the opportunity to explore a much more open-ended task. Students were expected to devise, enact, and critique their own scientific inquiry around a question in biology, chemistry, physics, or psychology, with students given many prompt topics in each field. For example, prompt questions in psychology included the following: Can you tell what something is just by touching it? Can you tell where sound comes from when you are blindfolded? Can things be identified by just their smell? Does the human tongue have definite areas for certain tastes? The program was organised in a similar way to the Adaptation unit, with students made aware of the prescribed learning outcomes from the AusVELS science curriculum from levels E to K. The students were given a rubric that specified these outcomes developmentally in relation to demonstrated skills in questioning and predicting, planning and conducting, processing and analysing, and evaluating and communicating, as well as a set of guide questions for their inquiry. The students were also able to access sample reports to guide their own investigations. The teachers provided feedback through topic approval, guidance with resources, and ongoing support for each phase of the student's inquiry. The open-plan settings were used in the same way as in the Adaptation unit, with video material (*Mythbusters,* 2015) used to engage and guide students, and teachers team-taught as in the previous unit. However, in this unit, teachers assisted individual students at their point of need. "With *Mythbusters* there was so much diversity right from the get go." Bob noticed the atmosphere of industry and harmony in the classroom. "The classroom was really humming. Some students were working outside, Steve was assisting students with experiments in the laboratory, Sue was helping students to write their reports and I was assisting students with psychology experiments". Bob thinks the key to successful team teaching is to "make the call according to each team's particular dynamic. You need to use that specialisation to meet the diverse needs and interests of the students".

The student survey conducted at the end of the unit revealed a high degree of satisfaction with the degree of choice, the freedom to choose and work on individual tasks, and to work in different spaces. However, the teachers were not entirely satisfied with the quality of the evidence of learning and understanding provided by most students. Bob thought the unit showed up the gaps in basic scientific understandings about laboratory equipment and safety, drawing accurate diagrams, and writing up results in a scientific report. These have since been addressed in a new preparatory chemistry unit, *Marooned*, which in future will lay the groundwork in basic scientific knowledge before the open-ended unit *Mythbusters* is attempted. More checks and balances were also needed to ensure that students were completing tasks in a timely manner.

One of the great successes of the unit was the quality of the scientist-student blog interactions. We report here briefly on the inquiries of two students, Sarah and Nerissa. Sarah undertook a "corrosive combinations lab report", and Nerissa studied the electric voltage generated by potatoes. We consider that these interactions heightened student interest through their novelty and expert input, and by enriching the quality (and challenge) of the investigations.

Sarah: Corrosive Combinations Laboratory Report

In her experiment, Sarah aimed to identify the efficiency of corrosive properties in soft drinks, using five beakers "with four different types of soft drink and one with water as the control to have something to compare to". In reporting on the process she claimed that "next you get 10 nails of the same size; five steel and five stainless steel. Put one type of nail in each jar. Leave these jars for 7–14 days. Once taken out, weigh all nails on a scale which goes down to 0.00g. Calculate the additional weight. This will show corrosion on the metals". Renée Webster, a fuel chemist, posted the following reaction on Sarah's blog:

> Your experiment sounds good but I have a couple of questions for you: 1. I think you probably planned to do this but just forgot to write it down, are you going to weigh the nails before as well as after? 2. What is the property of the soft drinks that you think might affect the corrosion? Is there any way you can test or measure this before you start? I'm interested in your statement that chemistry experiments only have to be done once- what makes you think this? Looking forward to your answers.

Sarah responded:

> I did weigh the nails before, throughout and at the end of the test but forgot to include that in this post. I am not sure what properties of the soft drink would cause the corrosion and I am not really sure how I could find that out. I believed that doing the experiment once would be enough when I begun but

> now I see that with multiple tests, I would get a better and more accurate result. Thanks for having a look at my blog, Sarah.

Renée responded:

> Hi Sarah, your final report looks really good. The multimedia you included really helps to understand your experiment and your data collection was thorough. I was interested that you mentioned a decrease in volume of the soft drinks and attributed it to the corrosion reaction. Do you think there could have been evaporation as well? Could you test this variable I wonder? Good work, Renée.

Nerissa: Electric Voltage Given Off by Potatoes

Nerissa's original hypothesis at the start of her experiment was that larger potatoes will "give off" more electrical energy than smaller ones. "The potatoes with a larger mass have a greater area in which to store energy, therefore they will give off more electrical energy. The potatoes all up won't give off a lot of energy, but I might be surprised".

Renée responded:

> Hi Nerissa, I like your experiment idea. Sometimes in my job I work with fuel made from plants so I like to see another way to bring energy and living things together! I'm a bit confused about the first part of your experimental plan; "10 potatoes of 4 different masses". Are you cutting the potatoes so they weigh the same, or you've just managed to carefully select whole potatoes of the same weight? Also I wonder if you are using the same variety of potato or different ones? Looking forward to your answers, Renée.

Nerissa blogged back:

> I'm going to cut down the potatoes until they are the same mass, the potatoes will all be white potatoes of the same variety.

Nerissa reported on her approach to the investigation, and Renee responded:

> I have one more question, I hope you don't mind. How did you decide to put the electrodes 2 cm apart? Do you think a smaller/larger distance would affect the voltage? Not necessarily something you want to test in this experiment, I am just curious.

After recording the voltage of 10 peeled potatoes Nerissa concluded that "the larger potatoes only had a slight voltage difference from the smaller potatoes, the juiciness of the potatoes affected the volts more than the size did" (Figure 8.2).

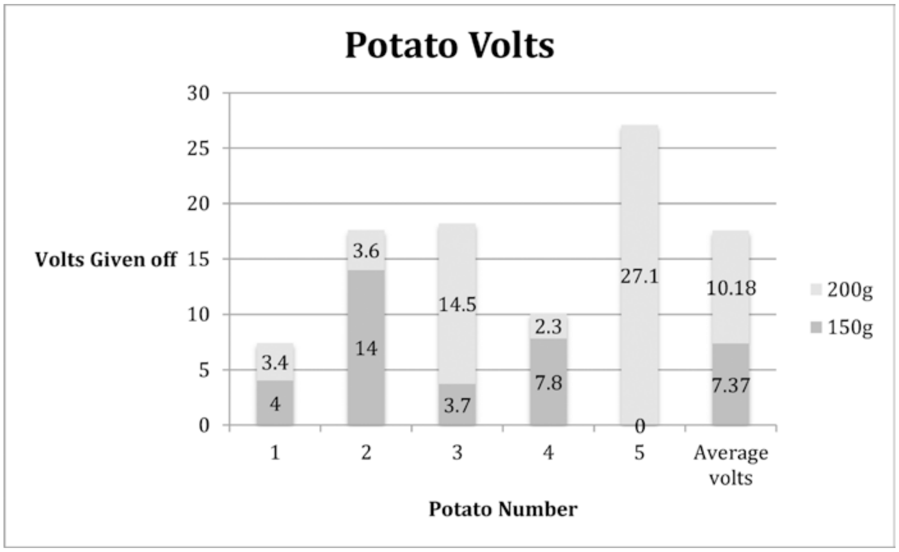

Figure 8.2. Nerissa's graph comparing potato size and volts

Renée blogged back:

> Hi Rachel, super work on your experiment, and how exciting to get a nice result that was different to your hypothesis! Did you judge the moisture content just with your sight and touch? Do you think there's a way that you could maybe measure the juiciness of the potato? Well done on the planning of your project too, this definitely would have helped you get good data. Renée

Another scientist, Tim Moore, an electrical engineer, also responded to Nerissa's results:

> Hi Nerissa, it's always interesting to see a stand-out result! Did this potato seem to be juicier than the others you tested? If it's producing a higher voltage it might be because it has more of the active elements in the juice that cause the voltage to occur, or possibly the juiciness just allows the electricity to flow a bit more easily. There could also have been juice on the volt-meter prongs. If the potato has dried out already don't worry too much – this is something you can keep an eye on from now on. And if you're not already, give the volt-meter prongs a wipe-down between each potato, so one potato doesn't give voltage to another! If you'd like to talk about it on Skype we can set up a session during your class time – let me know what times you'll be around if you want to talk it through! Tim

In her final discussion of her experiment, Nerissa noted that "to improve the data collected I could have monitored the juiciness of the potato and timed how long since I peeled the potato. To improve the accuracy of the whole experiment I could have double-tested each potato in different areas of the potato".

These blog exchanges indicated that the scientists engaged with the students as informed scientific inquirers, expressing serious interest in their investigations. They did not provide ready-made answers but used their feedback as an opportunity to ask questions that encouraged the students to extend their thinking on the topic, to consider a new method of investigation, a new or alternative hypothesis, or a possible alternative solution. Some students, according to Bob, were over-awed by this communication, but as we can see from these examples, others were able to respond to the feedback in a way that revealed they were utilising it to further their reasoning.

Approximately 20% of the class voluntarily participated in the global science forum in both units. Bob hopes to extend this participation as he believes it provides "an authentic audience for the students' work". He finds students are inspired and grow in their interest in science and understanding by participating in authentic interactions in a serious scientific forum. Students also realise that their teachers are not confined to those adults physically present in the classroom and gain confidence to extend their virtual networks. These exchanges and student reasoning highlight the value of: (a) students choosing their own topics for investigation, and having access to timely multiple providers of expertise; (b) teachers encouraging the use of ICTs to facilitate this access; and (c) a structured but flexible personalised curriculum that accommodates these aspects.

PERSONALISING SCIENCE THROUGH STUDENT REASONING OPPORTUNITIES

> Two years later, other teachers tell me that they can tell which students I had taught in this project. They are now better team workers and better problem solvers. (Teacher)

In making and justifying scientific claims through constructing and explaining multi-modal representations, students also have opportunities to personalise their understanding of topics (see Tytler et al., 2013). This focus on collaborative consultation, as noted by Kuhn (2015), encourages both personal and collective meaning-making around claims, warrants and evidence, where the teacher can challenge and guide student reasoning. Here we report briefly on two further examples of these shared reasoning processes in a Year 10 science class at Waratah College, a companion school in our study. These students had undertaken this science unit because of a school requirement that they must complete a minimum number of science units. The class was conducted in an open-plan setting, but in this case with one teacher working with a group of 25 students.

Atomic Structure and Electron Shells: Isotopes and Half-lives

While undertaking a study of atomic structure and electron shells, after the teacher had explored students' current understandings of why dental patients wear an apron for X-rays, she introduced the concept of isotopes, and guided further discussion about nuclear reactions and differences between elements. Depending on their perceived relevance by the teacher, the students' initial ideas were sought and explored. After a review of individual students' written accounts of isotopes, some students recalled a previous discussion about the concept of half-life. The class was asked to demonstrate their understanding of models of half-life using M&Ms (a coloured confection marked with the letter M on one side). Some students placed their M&Ms in a linear fashion, alternating marked and unmarked sides. A few students chose to tip the M&Ms onto their tables and removed any M&Ms that did not have the lettering facing upwards (see Figure 8.3).

Figure 8.3. Students sorting labeled from non-labeled M&Ms

They repeated this activity with the remaining M&Ms and plotted the results. The other students, after some discussion linked to previous experiences where they had seen half-life graphs, adopted a variation of this approach to describing half-lives. Finally, students compared the general shape of their graphs from this activity with published half-life graphs to determine how these different graphs supported the concept of half-life and the differences between the graphs. In addition, they talked about how the shape of the graph could differ if the isotope had a longer or shorter half-life. The teacher had accustomed this group of students to explain their ideas, challenge one another, and justify their own claims and understandings. For these students, it was natural to complete the class with discussion about the part that

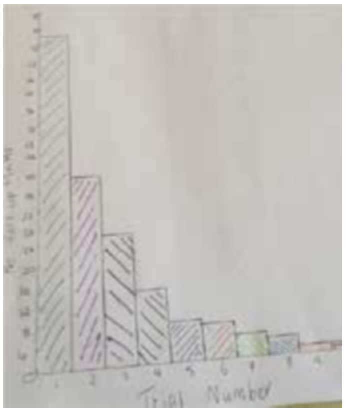

Figure 8.4. Student half-life graph

chance had played in the process. In this way, students built explanatory shared accounts that connected past and current experiences:

Teacher: Will your rate of decay ever become zero?
Student: Yes. Because you will have none left.
Teacher: Can you show me why?
Student: If 24 decay, we have 28 left. If 13 decay, we have 15 left. If 8 decay, we have 7 left…. eventually one decays and we have none left.
Teacher: Is this what happens in real life?

The resultant discussion explored the concept of large numbers of atoms decaying. The group eventually came to the conclusion that the rate of decay would decrease so much that it might be difficult to detect:

Teacher: What patterns did you find in your graph?
Carl: Mine was fairly even.
Eva: Mine wasn’t. It wasn’t even because it involved chance.
Megan: Mine halved every time.
Ben: That’s different from what we got.
Teacher: What would happen in real life?

Pause

Teacher: What could affect half-lives and how they decay?
Ben: The temperature. It can’t decay if it is frozen.
Carl: In areas where it is frozen, there is no radioactivity decay.
Gwen: But there is always background radiation.
Teacher: You mean that in Antarctica that there is no radio-active decay?

Carl:	There is always background radiation. It is found everywhere. It is just another chemical.
Teacher:	How does this affect how isotopes decay?
Steve:	It mixes with another element. If they have different half-lives, what would be its half-life?
Gwen:	Would it affect its half-life?
Ben:	They would keep their own half-life.

Students discussed their ideas and justified them from their observations and past experiences. They modified their explanations as evidence was provided and they showed how their ideas were viable for the initial claim. While classroom discussion was dominated by some students, over the whole lesson almost all students participated. Some students, who lacked confidence at the beginning, were quieter at the introduction of a new concept and became more involved as the lessons progressed until a new concept was introduced where this hesitancy was again apparent.

Motion and Forces

To introduce this topic, students were asked to summarise their journey to school in writing (mode of transport, distance covered, time taken), compare notes, and then translate their understanding into a graph of either distance or speed over time, with

Figure 8.5. Student timing balloon movement on fishing line

some examples shared on a whiteboard. Other students physically labelled places of constant speed, as well as increasing or decreasing speed on the graph, and had to justify their decisions. The teacher further tested their understanding of motion by having students construct a distance-time graph of a video of Usain Bolt running a foot-race, with students asked to focus on changes of speed. The resulting discussion talked about speed, constant speed, velocity and acceleration.

The class was then asked to reconstruct their understanding of motion. Some groups attempted to show this by attaching an inflated balloon to a straw that had a long fishing line running through the straw, taking measurements that would allow them to accurately plot a motion graph showing time separately from distance or speed. The imperfections resulting from the motion were discussed as students compared graphs with the observed motion in the Usain Bolt video. The students mostly measured the distance the balloon travelled until it reached the end of the fishing line and how long it took to travel this distance. One group tried to measure the acceleration of the balloon. When they presented their views, other students questioned their account, drawing their attention to the difficulties in measuring acceleration, especially over a relatively short distance. This discussion led to the students realising that the suggested time taken for the inflated balloon to travel the distance was difficult to measure because the time taken to travel the distance was only slightly less than a person's reaction time. The class was asked how they could address this challenge by first writing reasons, demonstrating their suggestions, and then modifying their suggested improvement. The class was constantly asked to consider how their individual understandings reflected what they were observing or what they were currently claiming.

These students not only made claims through supportive collaboration, they looked for evidence to support or challenge their claims, constructed an explanation, tested their assertions, and linked their views to both past learning and new situations. This collaboration was aimed at developing a higher quality response than if they had worked alone (Littleton, 2011). Students needed to probe one another's thinking so that their responses were more considered. The resulting dialogue allowed them to clarify understandings in a non-threatening way. In student interviews, they remarked that, at times, discussion with fellow students resulted in a better understanding than teacher-directed learning did. They constantly asked questions that challenged the robustness of each other's claims:

> Listening to other students helps me understand better, not just listening to the teacher's explanation is good. It helps you to understand in a language you know. (Student 5)

Students asked many more questions than they had previously using traditional teaching techniques. The class was not dominated by a few students and had relatively few students asking minimal questions. In this type of class, the teacher's role was to ask questions that tested and extended current student understanding rather than to supply answers. These teacher questions were rarely closed or simple response items. The teachers, who used wait-time to understand students' thinking and reasoning, felt rewarded by increased student engagement, interest, and participation in the learning. The students' views were supported by the teachers' comments:

> Interviewer: What has changed during this last term of teaching?
>
> Teacher: I was more careful about what students said. I used more of what they already knew. For instance, choose eight elements from the periodic table and tell me what you know about them.
>
> The answers in the exams were more on track with more detail than there had been before. Some of the answers compared to other years were much more insightful. There was more detail in their drawings.
>
> It resulted in a confidence boost with students. They became more confident to become involved in class discussion and activities. They learnt more than they generally did. This year there were much more 'why', 'how come?' or 'hang on, if we did this…" questions. The student questioning was a lot more insightful.
>
> They can explain and justify their thinking, whether they were right or wrong.
>
> The willing students came up to the board and had a try. The girls particularly gained confidence. Their friends would prompt assistance. Everyone is expected to have a go.
>
> Giving the students time to do something is more important than rushing through the material.

Building explanatory reasoning and argumentation skills has drawn considerable attention from science education researchers in recent years (Osborne, 2010). Understanding and justifying causal links are significant demands in deep scientific understanding, but can be enabled by students developing, justifying and sharing representational claims (Tytler et al., 2013). When the teacher focuses on students' thinking and reasoning with a series of representational challenges, the teacher can examine the robustness of these claims to support quality conceptual learning (Waldrip, Prain, & Carolan, 2010; Prain & Waldrip, 2006).

CONCLUDING REMARKS

Our case studies point to key affordances of open-plan settings that can enhance students' interest and learning in science. These settings can act as a catalyst to enable and prompt teachers to devise a rich developmental science curriculum that:

(a) enables tasks to be differentiated to address diverse student capabilities and interests; (b) can be team-taught drawing on the particular expertise and interest of teachers in the team, and (c) enables students to connect science learning with their everyday worlds. The first two case studies demonstrate how a heavily didactic approach to teaching can be avoided by restructuring classes to optimise student group and individual work and timely teacher coaching opportunities as required. In this program the students had access to current scientific agendas, discoveries, and methods through virtual meaningful contact with practising scientists via skype and blogging. In these ways the program's design incorporated features recommended in the literature as likely to engage science learners. The third case study indicates that the settings do not preclude a more traditional organisation of learning, where one teacher worked over time with a group of students deploying a range of reasoning tools for learning in this subject.

As noted by Bob, the teachers did not view the Melaleuca science program as providing exemplary learning experiences in all aspects, but rather the outcomes pointed to workable strategies to personalise science learning for this group of students with a team of teachers. There were still challenges around setting high expectations for all students, and encouraging them to use a wider, more challenging range of representations to make advanced claims in science topics. Students also need to learn how to negotiate and customise learning goals and practise co- and self-regulated learning experiences. To move from reluctant bystanders in this subject, students need opportunities to develop their capabilities and confidence as contributors to a collective learning community.

Our case studies indicate that student learning and engagement can be personalised in science when teaching and learning experiences are based on a series of representational challenges, where:

- students generate representations to actively explore and make claims about phenomena;
- teachers and students ask questions that seek clarification about the robustness of student ideas in a supportive environment;
- there is an interplay between teacher-introduced and student-generated representations where students are challenged and supported to refine, extend, and coordinate their understandings;
- adequate links are made to student interest, current learning, and past learning in a manner that facilitates this process as a continuum rather than an isolated discussion; and
- students' input is not seen as replicating past teaching but as a reasoning process that is robust, relevant, and challenging to their context.

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