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THE AFFECTIVE DIMENSION OF ANALOGY

Student interest is more than just interesting!

1. INTRODUCTION

The many ways that people use analogy to create and communicate knowledge have interested scientists, educators and psychologists for more than 40 years (e.g., Oppenheimer, 1956; Glynn, 1991). It is not surprising, given the popular view of science as a logical and rational enterprise, that scientific, empirical and cognitive methods have dominated analogical research (e.g., Gick & Holyoak, 1983). The rational approach (sometimes called the cold-rational view) has yielded significant benefits for teachers in the form of the FAR guide (see pp. 20-21); however, cognitive studies reveal little about the reasons why teachers and students are attracted to analogy in the first place. This chapter reviews a sample of the small group of studies that comment on the motivating potential of teaching with analogies and concludes that the affective dimension of science analogies should be a research priority. Only by better understanding the allure of analogies can we further enhance the inquiry and teaching power of analogies.

Certain concepts like refraction can only be explained by analogy (Harrison, 1994) and analogies are widely used as conceptual change tools, but the use of analogy to raise learners' interest levels is rarely reported. In their review of the motivational literature on conceptual change, Pintrich, Marx and Boyle (1993), argued that affective factors are largely ignored in concept learning studies. They claimed that affective or "hot-irrational" issues are just as important in concept learning as cognitive factors because interest determines the level of student engagement in cognitive activities. This chapter therefore asks "what do we know about the interest-generating dimension of analogies?" and, "how do interesting analogies enhance cognitive learning?"

2. THEORETICAL BACKGROUND

Two analyses of analogy use in science teaching discuss the conceptual growth potential of analogies (Dagher, 1995; Duit, 1991). Duit showed that analogies are

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effective conceptual change agents because they enhance understanding by making connections between scientific concepts and students' real-life experiences, and by helping students visualise and manipulate abstract ideas. He pointed out that analogies "provoke students' interest and may therefore motivate them" (1991, p.666) but interest is the last factor in his list of analogy's advantages. Duit explains in detail the constructivist benefits of analogy, but does not explore the motivational power of analogies and models. The absence of interest and motivation in review papers is easily explained: few studies of analogy discuss this factor.

Motivation and interest are key ingredients in effective learning. If students are not attracted to the concept or context, learning will be limited. It is the student who decides whether or not to engage in concept learning (Pintrich et al., 1993). Students choose to engage in a topic for a raft of reasons including interest in the task, rapport with the teacher, perceived value and utility of the knowledge, self-efficacy and the social milieu. This last factor is often ignored when teaching with analogies. Classrooms are social settings and Vygotsky's socio-cultural theory (van der Veer & Valsiner, 1991) helps us understand why social interaction is useful and it suggests ways teachers can enhance their planning and teaching (e.g., by choosing analogies that are located in a student group's *shared* 'zone of proximal development'). Social knowledge and experience is the most effective source of teaching analogies and both Glynn (1991) and Treagust, Harrison and Venville (1998) insist that analogies be familiar to the students (i.e., drawn from their life-world). If an analogy is not familiar, it should not be used.

Analogical thinking accesses useful structural and relational information from a learner's repertoire of familiar instances or events (the *analog*) and maps structural and relational knowledge onto the unfamiliar science concept (the *target*). The familiar analog informs the student about the unfamiliar science concept. Analogies are especially interesting and motivating when the teacher's analog can be enriched from the students' own experience. If, however, the analog is unknown to or poorly visualised by students, they will feel marginalised or frustrated and this will lower their interest in the analogical discussion. Interest and engagement are crucial to learning — it is "important to begin [by building] the connections between the motivational and the cognitive components of student learning" (Pintrich et al., 1993, p.168).

The *depth* or *rigour* of an analogy also contributes to learning. Gentner and Markman (1997) show that relational learning (as opposed to instrumental knowledge) is the desideratum of effective analogies; therefore, the analogies discussed in this chapter are limited to ones that enhance relational understanding.

Investigating the affective dimension of such analogies is facilitated by Pintrich et al.'s (1993) motivational and self-efficacy theories. Their research program shed light on the benefit of examples like the wheels-refraction analogy and Thagard (1989) insists that motivational factors enhance conceptual change. Consequently, I scrutinised studies in which I participated to find instances of analogical affect on concept learning. These studies comprise Harrison (2001), Harrison & Treagust (1993, 2000), Treagust et al. (1996; 1998).

3. METHODOLOGY

Published papers and unpublished theses were searched to identify potential instances where interest and motivation likely influenced the learning outcomes of teaching analogies. Because these studies dealt exclusively with textbook or teacher-generated analogies, the following analysis is limited by this choice. The concepts and analogies found in these studies were taught by experienced teachers to students in Grade 8-10 science and Grade 11-12 chemistry and physics. As these cases already are reported in detail, their choice was purposeful (Patton, 1990) as they contained instances of analogical affect. Each case was chosen because it contained evidence showing that students were keenly interested in some part of the analogical episode. Nevertheless, for each case, the original data were revisited to clarify events and some new data are added. Analyses like this often are more subjective that the original article because of the time lapse; however, in a converse sense, new interpretive perspectives can add to the data's meaning and impact.

A new perspective that informs this study is the multi-dimensional interpretive perspective elaborated by Tyson et al. (1997). This framework argued that better sense could be made of conceptual change episodes when the epistemological, ontological and motivational dimensions of the teaching and learning were integrated and interpreted together. This disposition is adopted here to try and shed new light on the classroom vignettes that are presented in this chapter. Space limitations mean that the vignettes are compressed and the reader is referred to the original articles should more information regarding each study's theory, method and interpretation be required. The intent of the chapter is to revisit the cases to derive new sense and to generate research questions that will guide future studies into the affective dimensions of science analogies and models.

4. CASES OF AFFECTIVE ANALOGICAL TEACHING

4.1 The Wheels Analogy for the Refraction of Light

Context. A Grade 10 physics class at a girls' independent school was taught by Mrs Kay (pseudonym). Colleagues identified Mrs Kay as an expert teacher and when interviewed to find which analogies she planned using in her lessons, she expressed a desire to trial Paul Hewitt's (1992) wheels analogy for the refraction of light. Mrs Kay found the analogy interesting and felt that demonstrating it made the event real and reduced the possibility of alternative conceptions. She was teaching optics to two Year 10 classes and, as one class had already studied refraction, the analogy could only be used with the second class. The classes were of comparable ability permitting us to later compare the conceptual change effects of the analogy. The wheels analogy was published by Harrison and Treagust (1993) and the comparative study, with the motivational event discussed here, was reported by Treagust et al. (1996). In the 1993 study, Mrs Kay was interviewed pre- and post-lesson and nine girls were individually interviewed post-lesson. The lesson in which the wheels analogy was demonstrated was recorded and transcribed.

The wheels analogy. Mrs Kay enthusiastically led her students through the analogy. First, she demonstrated how light bends towards the normal when it enters a perspex block and then bends away from the normal as it exits the perspex. The top diagram in Figure 1 depicts the set-up: a light box and a large rectangular prism were blue-tacked to the white-board. The room was darkened and the ray bending was demonstrated, and questions like "why does the ray bend towards the normal when it goes from air into Perspex?" were asked.

Mrs Kay introduced the analogy by drawing attention to a large hard card butting up to some soft carpet, a pair of wheels, and some bright fluorescent paint. The students were attracted to the paint, wanted to know its use and excitedly asked "what if we spill it …?" Mrs Kay first conducted a 'dry-run': she rolled the wheels so that they obliquely rolled from the hard card onto the soft carpet. She drew attention to the change in the wheels' direction as first one, then the other, slowed down. Then it was time for the paint. She invited a student to liberally coat the wheels with paint – "this is what all the paint's for … coat the pair of wheels with this nice fluoro paint …" – this was motivating because the bright paint was already a point of interest. Mrs Kay then asked another student to push the paint-coated wheels so that they rolled obliquely from the hard card onto the soft carpet. As the wheels crossed the join, the wheel tracks bent towards the normal. The students were impressed and were talking their way through the analogy with the teacher when a student interjected with

> it's … it's like on the farm when we drive the tractor along the [dirt] road .. sometimes your front wheel runs into a patch of sand and the tractor steers off the road. It sorta pulls the wheel out of your hand when one wheel slows down straight away …

Mrs Kay took this up and added

Mrs Kay:	Mrs P was saying that I should make this point about car wheels changing direction when they go onto a different surface. Mrs P's daughter was driving a car on holidays when she got one wheel on the gravel, and when she got one wheel on the gravel, what happened?
Student:	It slows down.
Mrs Kay:	That slows down, so what happens to the car?
Student:	It goes off the road …
Mrs Kay:	The car spins round if one wheel slows down while the other's going fast, the car can spin. Now Mrs P's daughter got the car out of control and wrote it off … but they were all lucky because they all got out unhurt.

In the follow-up interviews, several students related the 'wheels slowing down and turning' to experiences they had in driving farm vehicles on sandy tracks and skateboards running off concrete paths onto grass.

Discussion. This exchange is significant because the students' concept learning was enhanced by the spontaneous introduction of familiar experiences. This helps

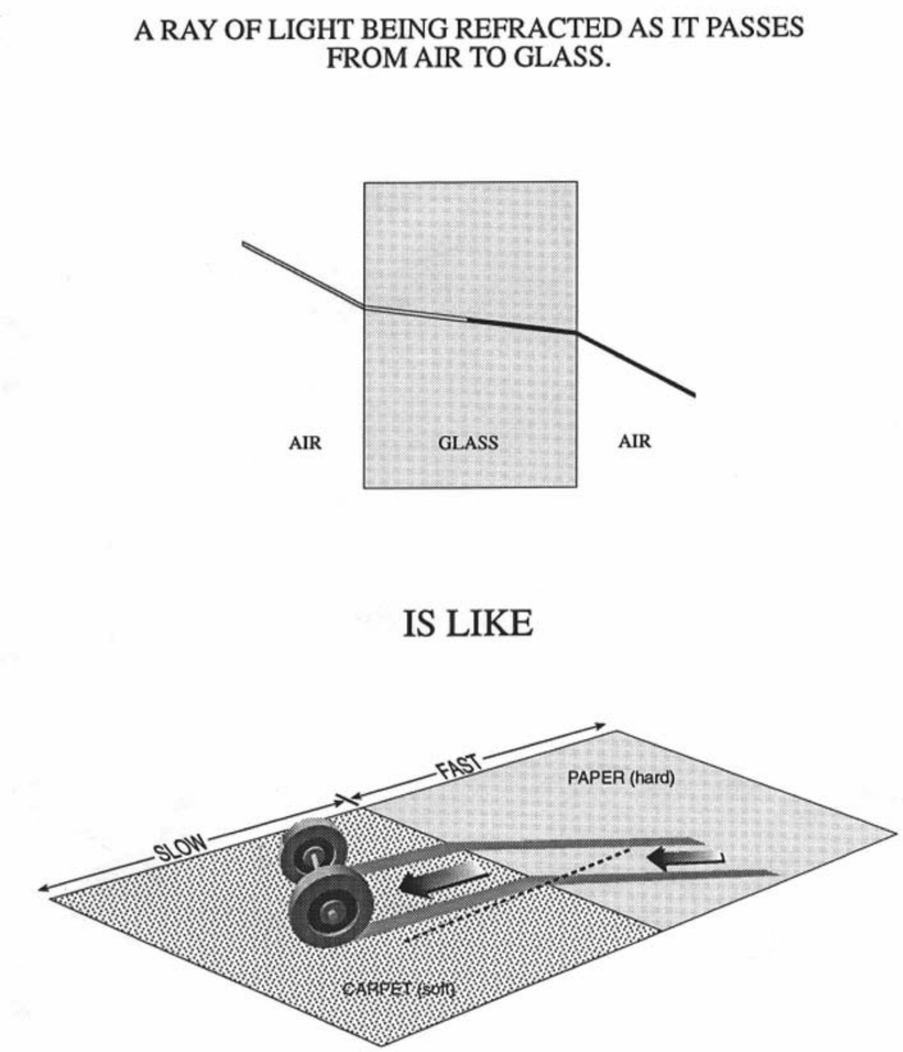


Figure 1. The wheels analogy for the refraction of light

to explain why some analogies are effective and others are not. When the students are able to connect the analog—target to their experiences, they are stimulated to explore the analogy in deeper and more meaningful ways. In this case, I suggest that student interest began with a superficial attribute (the fluoro paint) grew as they added everyday examples and this helped them ‘analogise the analogy’ to their life experiences. Personalising the analogy enhanced relational concept mappings of the type advocated by Gentner (1983). When the conversation flowed to everyday matters, the students became excited, willingly sought connections and offered new examples. The opportunity for them to tell their stories strengthened the conceptual links that they were making by adding personal relevance. Successful connections like these enrich the analogical mappings because the students see how the science concept explains their everyday happenings.

Eight of the nine student interviews demonstrated an understanding of refraction in terms like, ‘the one side of the ray slows down before the other side so it bends like the wheels’. Jan described it like this:

> Because one edge or side of the light beam hits the different medium before the other, so it slows down and the other one keeps going so it sort of bends until the other one catches up and they're both travelling on the same medium. ... One wheel hits the carpet at ... before the other wheel, just like one edge of the light hits before the other edge of the light.

To verify that the students had developed a relational understanding of the wheels-refraction analogy, they were asked if they could explain why light bends away from the normal on leaving the perspex. Cara explained that light bends

> … away from, the normal, because it is, um, the same idea, but the other one comes out from the denser medium first, so it goes faster before the other one catches up, and then it goes on parallel to the other side ... it's the other side that gets there first because it's on an angle and it bends back or goes back on the parallel of the ray it started on, before it got into the dense area.

These vignettes are part of an larger case and further information is available in Harrison and Treagust (1993). The vignettes suggest that it is likely that the students’ interest in the wheels analogy contributed to the analogy’s cognitive effect.

4.2 Analogy and Conceptual Change

Knowing that one Grade 10 class studied refraction with the analogy and the other without led to a study of conceptual change effects of the analogy (Treagust, Harrison, Venville & Dagher, 1996). In this interview-about-instances (IAI) study, conducted three months later, 25 of the 29 students who were taught refraction with the wheels analogy were interviewed and 14 of the 25 who were taught without the analogy were interviewed (using the same protocol). The non-analogical explanation for the second class stated that the side of the light ray that enters the perspex first slows down before the other side of the ray, thus the trailing side travels further than the preceding side causing the ray to bend.

This secondary study explored long-term concept learning where interest can play a role. While this study was not searching for interest-based events, Dana’s interview showed the importance of motivation. At first, Dana was unable to explain refraction, insisted that she was “no good at science” and told how she failed the optics test.

The interview. The interviewer used a think-aloud protocol in which the students conducted activities and were presented with familiar and novel IAI problems. For example, the students were shown two striped pencils placed respectively in tumblers of glycerine and water, and asked to explain why the pencils appeared to break differently at the liquid's surface. Then followed three ray-tracing diagrams that the students were asked to complete (Figure 2 includes a question and Dana's response). Cues like, "how would you explain that to a friend?" were included to encourage the students to reflect upon their own conceptions and to elicit conceptual status information.

Dana's response. Dana was disinterested and vague early in the interview. When asked "what do you think will happen to the ray of light when it hits the surface of the water?" she replied, "it will probably be stopped and spread" (see the lines marked 1 in Figure 3). To the question, "Why does that happen?", she responded, "I don't know", and a similar reply was given to the following questions. Dana did not volunteer any explanation, however simple, to account for refraction.

The planned cues for reluctant students were then presented.

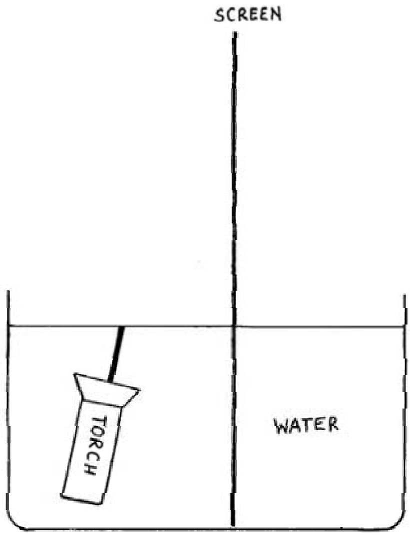
Int.	Can you think of any simple analogy that would help you explain to a friend why those pencils appear to be bent?
Dana	No. I don't think I'd be able to explain it 'cause I don't know myself.
Int.	Right, did Mrs ... use an analogy when she taught you this?
Dana	Umm ... she used a car type of thing with wheels when it was changing from a piece of carpet to paper.
Int.	And what happened when the wheels went from carpet to paper?
Dana	It bent because one wheel got onto the paper before the other one and one is rougher than the other surface.
Int.	So what happened to the wheel that got onto the paper first?
Dana	It went faster so it turned.
Int.	OK. So one wheel was going faster than the other was it? What happened when the other wheel got onto the paper too?
Dana	Then it just went straight from there …
Int.	Does that fit in, in any way with light?
Dana	Yes, because light changes faster in air than it does in water.
Int.	Alright, let's come back to this one [Dana's sketch in Figure 3]. What will happen when the beam of light hits the surface between the water and the air?
Dana	It would probably be bent that way.
Int.	Alright, you draw the line now [line 2, in Dana's sketch]. Nice heavy one so we can pick that from the original [faint] lines. OK. did the wheels help you work that out?
Dana	Yes.
Int.	Did you initially remember the wheels?
Dana	No.

Dana then returned to the IAI cards and the pencils problem and her revised answers were among the best of the 39 students.

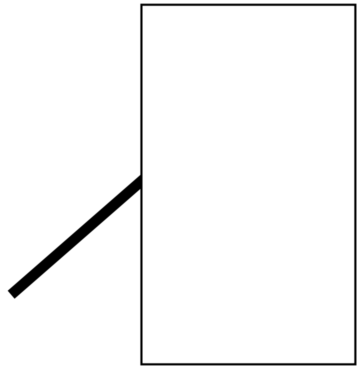
Listening to the tape-recording provides information not evident in the transcript. Prior to recalling the analogy, Dana was quietly spoken and disinterested. After recalling the analogy, she was enthusiastic and the interview produced another four pages of transcript. Dana's initial answer to question 1 was inaccurate and showed

1. If we place a light source in the water as it appears in this figure, what do you think will happen to the beam of light when it hits the surface of the water? Feel free to draw your prediction on this paper. Explain.

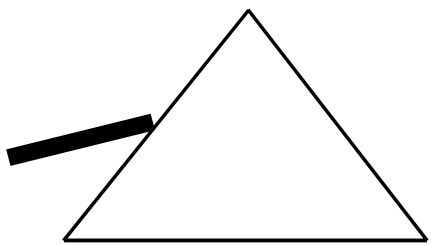
Sketch 1



Sketch 2



Sketch 3



2. a. If a beam of light strikes this glass block from the side shown in this figure, what happens to it? Draw the direction of the beam going through the block if the light is turned on from this side.
   b. How would you explain what you have just drawn to a friend, who has not studied these ideas, so that she could understand what is going on?
   c. Are there any other lines that you could draw on this diagram to show what is going on?

These three questions were repeated for Sketch 3.
A fourth question, not shown here, asked students to observe a pencil standing half immersed in a clear liquid and to describe and explain what they saw.

Figure 2. The three interview-about-instances diagrams (positive images) used in the interviews.

Dana's sketches

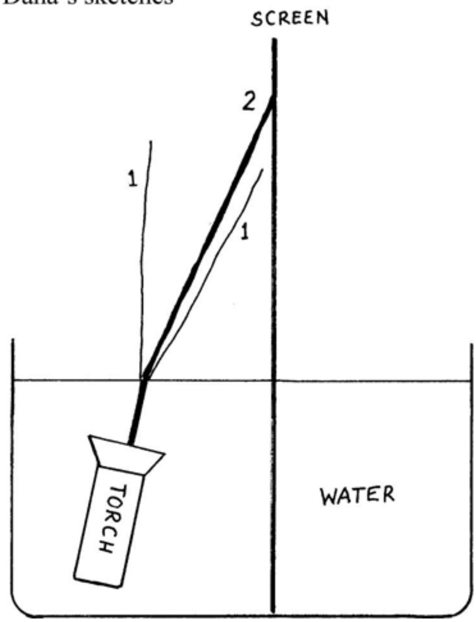


Figure 3. Dana's early (1) and later (2) responses to the torch in water (negative image) questions

little evidence of understanding. Recalling the analogy, led to her becoming dissatisfied with her initial answers and she confidently changed her vague sketch into one resembling the scientifically accepted response.

Discussion. Treagust et al. (1996) discuss the status of Dana's conceptual change after the analogy was recalled; however, the salient issue here is the role of the analogy in motivating her to engage with the questions and think about the problems. What does this mean? Dana is not alone, she belongs to a large group of students for whom physics (and science) lacks the relevance, interest and opportunity for them to grow in knowledge. Students like Dana do not fail science, science fails them because it does not excite their interest. School science no longer has an elitist mandate to cater only for those students who are capable of tertiary science studies. Disinterested students cannot be ignored as "lacking knowledge or ability". School science has a warrant to productively engage students in exploring the science that affects their lives. The *Beyond 2000* report (Millar & Osborne, 1998) asked, "Who is school science education for?" They insist that "teaching science is to enable young people to become scientifically literate – able to engage with the ideas and views which form such a central part of our common culture" (p.2006).

So, why are students like Dana not included in successful sense making about their world? It is not because they are unable because Dana was precise and accurate in her thinking once the analogy was retrieved from her memory. I suggest that the curriculum and her science class's culture, while better than many, still had a way to go before it included all who were able to learn in science. The cold-cognitive approach did not satisfy Dana's needs; but she was able to access an interesting analogy three months later and use it to solve problems she was entitled to expect to understand when the class studied optics and her knowledge was tested. Her failure was a failure of the teaching and testing regime to encourage her to show what she knew and could do. Science should interest all students; this is achievable and one way to build and sustain motivating learning environments is through the use of imaginative and relevant analogies. Most analogies come from the teacher's repertoire and students should be encouraged to contribute their ideas so that they can 'flesh-out' the analogy and see its relevance to them.

4.3 Teachers' Attitudes to Analogies

Teaching-with-analogies and models (Glynn, 1991) and the publication of cognitively beneficial analogies and models (Harrison & Treagust, 1993, 1994a, 1994b, 2000) has helped teachers motivate their students by providing them with interesting analogies. The following excerpt comes from interviews with 10 experienced secondary science teachers (Harrison, 2001). Follow Ian's enthusiasm as he talks about a favourite analogy that he used to heighten interest and explain inheritance principles to his low achieving Grade 10 class.

> The [students] saw videos with actual shots of chromosomes under the microscope but it meant very little to them until they actually made their own chromosomes with poppet beads and had a set of chromosomes which they then … mated with the person next to them, which they thought was really exciting. They had to go through the mechanism of dividing their chromosomes so that when they combined their gametes with the person next door they ended up with somebody who had a similar complete set of chromosomes. They were able to understand how … you end up with an offspring that has the same complement of paired chromosomes. Then we took that concept further by marking the beads as particular genes and then with their breeding they were able to … determine what offspring characteristics would be …. They started getting this idea that there was some predicability and they [were] capable of fairly high-level probability calculations. This class, allowing them time to pursue this model, arrived almost at the same end as the brighter kids but it took a lot more time. And it wouldn't have been possible without an analogy and a model that they can get their hands on …

Ian particularly enjoys teaching these students and offered this story when asked how he explained difficult concepts to such a class. Ian also related his nuts-and-bolts atoms analogy for chemical bonding (Australian Science Education Project, 1974) to show how everyday knowledge can motivate students.

Discussion. It is important to share Ian's enthusiasm for these strategies because they are *his* purpose built analogies and models. His analogies and models work because he designed them with his students' needs in mind. Ian was particularly enthusiastic about his 'breeding' analogy because he believed that it was interesting, familiar and matched his students' capabilities. There is an appeal to the students' sense of naughtiness when he says "they … mated with the person next to them, which they thought was really exciting". Teachers create these scenarios to captivate and engage students because they realise that students need help understanding how science can be made relevant to them.

Ian's desire to interest his students highlights a problem familiar to every classroom teacher: despite the best intentions of the teacher and the provision of excellent learning resources, many students who should learn, do not. The provision of ideal cognitive conditions cannot overcome student reluctance to learn when the student is disinterested and does not want to engage in the learning activities. "Three aspects of an individual's behaviour – choice of task, level of engagement, and willingness to persist at the task" determine the student's level of engagement and his or her learning outcomes (Pintrich et al., 1993, p.168). The popular constructivist principle that it is the student who decides whether or not to join in and learn can insulate us from the importance of interest and excitement. The role of teachers is to suggest interesting examples and analogies that will motivate their students.

Chemistry analogies. My third example is Neil who has taught secondary science for 15 years. Neil extolled the benefits of analogies as motivational and explanatory tools. He spoke for over an hour about the way he uses analogies to capture student interest and most of his ten analogies were advance organisers. This is how he explained his teaching of chemical bonding:

> … I don't often tell them where I'm going, I'm just telling them a story. I talk about being at the dance and having to prise people apart. The attraction is so strong, I have to put the foot in … like the electrostatic positive—negative ions … I talk about girlie bonding and I talk about blokey bonding around the bar or after a football game … that's like metallic bonding because they're all the same types with lots of energy floating around them …
>
> I'm a story teller and once I've got them in the palm of my hand, I say "Oh well, I've just explained to you the basic concepts we're going to do for the rest of the term … and then I'll go back and use these ideas again when I work through the four types of bonding. And it's funny because sometimes I'll get the kid with a bit of a sense of humour who will on their exam … talks about blokey bonding to explain metallic bonding, and I think if it's stuck with a few kids, and helps them explain, perhaps it does channel their thinking. Perhaps they can see the differences [in bonding types].

Discussion. Neil appeared to have just three analogical contexts: boy-girl behaviour, cars, and sport: contexts that interest Grade 11-12 students. His recorded teaching analogies fitted three types: type one focused on provocative ideas that were developed over several lessons (four analogies). In type two, he used motivational stories to illustrate and focus interest on key concepts (three analogies), and in type three he designed specific analogies for specific problems (three analogies). Neil believed that many of his story-analogies were successful because they were interactive; that is, he encouraged students to develop the story by adding comments and asking questions. This approach resembles Mrs Kay's discussion about cars running off the road. Neil's enthusiasm when telling his stories and describing the students' responses (some of them jokes at his expense) suggests a high level of enjoyment by both teacher and students. Neil's teaching analogies seem to fit the 'hot, irrational approach' to concept learning.

Neil's analogies, however, did not appeal to everyone. Sue told how "you remember them more than a textbook explanation [but] you say cars, and a lot of the girls just switch off". A similar finding emerged when another teacher used the Melbourne Cricket Ground to analogically model the spaciousness of a hydrogen atom; too few students in the class were interested in football and cricket to enable them to access the analogy's benefits. A successful replacement analogy employed the proximity of each student's home to the school and different sized balls were used to model the nucleus, electron and the space between them in a hydrogen atom.

5. CONCLUSIONS AND RECOMMENDATIONS

The paper's examples – the wheels analogy, Dana's story, Neil's teaching and Ian's interview show that analogies can interest students provided the stories are contextually, intellectually and socially familiar. Three recommendations seem pertinent: First, teachers need a rich and varied set of analogies that stimulate their own and their students' creative imaginations. When teachers and students co-construct analogical explanations using the students' shared experiences, effective learning often results. Second, teachers need a systematic strategy for presenting analogies so that the analogy's familiarity and interest is assured; the shared attributes are mapped in a way that enhances relational knowledge; and a means exists to check that the students realise when and where the analogy breaks down. This strategy is available in the FAR guide (see pp. 20-21). Third, it is important that we study which analogies interest students, why students are interested in these analogies, and which concepts are best developed using these analogies.

This chapter also has shown that expert and creative teachers carefully plan their analogies and understand the limits of their favourite analogies. Yet research shows that many analogies are ad hoc or reflex-like reactions to student disinterest and lack of understanding. Learning will not be of the desired type or depth while ad hoc analogies are retained. I recommend that only those tried analogies that can be presented in an interesting way be used to explain abstract and difficult science concepts.

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