Teaching school science within the cognitive and affective domains

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Contents

Abstract

In classrooms, science is usually taught within the cognitive domain while the psychomotor learning domain is achieved through performing science experiments in the laboratory. Although students attend civic and moral education and pastoral care classes where values and life skills are often taught directly, learning experiences in most school subjects such as science are still centred on preparing for high stakes examinations. It is therefore not surprising that affective domain learning outcomes are often the least considered when teachers plan or conduct their science lessons. This paper is a report on three school-based trial lessons in which students from two Singapore secondary schools were taught science concepts and skills in the usual manner with follow-up reflective activities requiring them to draw from their learning experiences parallel scenarios in their daily lives. The students were taught chemistry topics like reactivity of potassium metal (taught to a secondary 4 normal technical class), sedimentation as a separation technique (taught to a secondary 3 express class), and reaction characteristics of weak and strong acids (taught to a secondary 2 express class). At the end of each lesson, students had to discuss, reflect and respond to an everyday event or scenario which has characteristics similar to the chemistry topic or skill they had just learnt. This cognitive-affective integrative teaching approach aims to help students surface important values, positive social habits or effective life skills. Although this is not a research project but an exemplary teaching practice, observations of students' reflective responses to the tasks and feedback on learning experiences from students and teachers show great potential for this teaching approach to be a possible way in helping raise the profile of affective learning objectives in school science lessons.

Keywords: affective domain, analogies, reflection, school science, values education

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Teaching school science within the cognitive and affective domains

The school curriculum often covers the cognitive, affective and psychomotor learning domains. In classroom, science is usually taught within the cognitive domain while the psychomotor learning domain is achieved through performing science experiments in the laboratory. Although students attend civic and moral education (CME) and pastoral care classes where values and soft skills are taught to them directly, learning experiences in most school subjects such as science are still focused on high stakes examinations. It is therefore not surprising that affective domain learning outcomes are often the least considered when teachers plan or conduct their science lessons. With globalization and advancement in information technology, skills within the affective domain are becoming more relevant as these become the “must-have’s” for the 21st century worker-citizen (Ministry of Education, MoE, 2012; Organisation for Economic Co-operation and Development, OECD, 2012). Thus, the question that educators and teachers may need to ask is “How can we teach and prepare the younger generation to be that effective 21st century worker-citizen with an inquiring mind and a compassionate heart?” This paper is not an attempt to answer this question. However, it aims to share some ideas on how a typical school-based science lesson can be used to help students surface values and life skills so often mentioned by educators and business management experts as important to the 21st century society and workplaces (OECD, 2012). It is the belief of the teachers participating in this initiative that school science as an examination subject is usually taken seriously by students in class, and while they are seriously learning the subject their teacher can take the opportunity to help them surface values, positive social habits and effective life skills.

In this school-based initiative, secondary school students were taught science concepts using the usual classroom teaching-learning approaches that would effectively prepare them for high stakes examinations. The critical component of the science lessons, however, was the reflective activities on daily life experiences. The objectives of this cognitive-affective integrative approach to conducting school science lessons are: (1) to teach science concepts so that students understand them well enough to use them in solving conceptual problems, and (2) to develop an awareness among the students of the various values, positive social habits or life skills that they can relate to by drawing analogies with the science concepts learnt.

This exemplary integrative teaching approach was developed from the teaching experiences of the participating teachers and the ideas shared in the literature on how students are motivated to learn (Brophy, 2004; Stiggins, Arter, Chappuis and Chappuis, 2009). The teachers are convinced that when students understand the science concepts (within the cognitive domain) and are able to apply their new found knowledge and skills in completing or solving everyday life science-related tasks and problems, they will also be motivated to continue learning about values and life skills within the affective domain. The three trial lessons will therefore be used to identify the potential benefits and limitations of this cognitive-affective integrative approach to teaching school science, values and life skills.

Learning school science in the affective domain

All trained educators would be familiar with the cognitive, affective and psychomotor domains of learning described by Bloom (1956). These domains of learning are still applicable in all areas of learning (Buehl, 2009; Krathwohl, Bloom & Masia, 1964). However, the affective domain, unlike the other two, remains the least applied. It is a common observation among teachers and educators that students, especially those in high stake examination systems, often put learning objectives in this domain at the lowest of priorities. After all, few examination boards, if any, emphasize the assessment of learning objectives in the affective domain. This situation may explain the difficulties faced by teachers to teach values and life skills in class (Krathwohl, Bloom & Masia, 1964; Martin & Briggs, 1986). There are also many challenges to assessing affective learning outcomes in ways that are objective and reliable (Anderson & Bourke, 2000; Popham, 2010). Despite these hurdles, no examination authority would omit the affective domain learning objectives in their syllabuses. Usually there will be sections or brief descriptions on how values and life skills can be incorporated into the science curriculum, but most of these are left to the interpretation of the individual teachers teaching science in the classroom.

With these difficulties in incorporating affective learning objectives in mind, the teachers participating in this project recognized the importance of helping students do well in science examinations while at the same time supporting efforts to help the same group of students learn values, positive social habits and effective life skills. The strategy is to integrate learning objectives in both cognitive and affective domains by employing what may be described as a “reversed analogy”.

The use of analogy is well documented in the science education literature (Abell and Lederman, 2007; Harrison and Coll, 2008). Briefly, it involves explaining an abstract science concept (referred to as the target) to students by first describing an everyday life experience (referred to as the analogue) that may hold some resemblance to the science concept being taught (Harrison and Coll, 2008). For examples, the "lock-and-key" model is frequently used to explain the specificity of enzyme action, and teaching students how to classify objects is a common strategy chemistry teachers use when introducing the concept of periodicity of elements. When students see the similarities between something they are familiar with, they are more likely to understand the concept. In fact, they may even retain their learning longer and apply it to new situations by simply remembering the analogy (Harrison and Coll, 2008). In this manner, the use of a "reversed analogy" can similarly help students retain their understanding and appreciation of a value or positive social habit (the target) if these can be explained using a newly learnt science concept or skill (the analogue). The lesson trials described in this paper are therefore examples on the use of "reversed analogies" in school science. By using this strategy, teachers can adopt the cognitive-affective integrative approach to help students reflect and surface values and life skills (identified as the targets) from their learning experiences in science classes (where the analogues for the reversed analogies are created).

Methodology: Using "reversed analogies" in school chemistry

Tables 1 to 3 below summarise the teaching methods, the "reversed analogues" and the "reversed targets" for the three lessons shared in this paper.

Table 1. Lesson 1 on "Reactivity of Potassium Metal"

Lesson Information	Reversed Analogue	Reversed Target
Students: 32 Secondary 4 Normal Technical Stream General Science students Cognitive domain: Teaching of reactivities of metals Affective domain: Anger management (a life skill) Activities: Teacher talk, viewing of video clips on potassium reactions and completing a worksheet with	The emphasis in the cognitive domain was on the characteristic reactivity of metal potassium, a very reactive metal. It will react explosively if it comes in contact with air or water. To prevent it from exploding it is usually kept in oil, so as to keep it away from air or	The emphasis in the affective domain was on using the reactive nature of potassium as a lead-in for students to reflect on their own social behavior when they were involved in a heated argument or misunderstanding. Questions like "Am I as 'explosive' as potassium metal in the way I interact with people around me?"

questions on potassium reactivity and a reflective task on anger management	water.	were asked in class. The teacher had attempted to help students see a parallel between the use of oil (to prevent potassium from exploding) and themselves in trying to calm down an angry classmate. (See sample responses in Annex A).

Table 2. Lesson 2 on "Separation Technique: Sedimentation"

Lesson Information	Reversed Analogue	Reversed Target
Students: 30 Secondary 3 Express Stream Pure Chemistry students Cognitive domain: How sedimentation works (heavy particles settle to the bottom of the container) Affective domain: Being resilient, calm and clear minded (positive values and habits) Activities: Teacher talk, class discussion and completing a worksheet with questions on sedimentation as a separation method and a reflective task on responding to a crisis or managing anxiety.	The emphasis in the cognitive domain was on settling muddy water by leaving the container undisturbed over a period of time. The heavy particles will settle to the bottom and a clear layer of liquid water will be seen above the layers of settled sand particles. Stirring the settled mixture will return it to its muddy appearance as the small sand particles become temporarily suspended in the water again.	The emphasis in the affective domain was on the state of our minds when we are anxious, angry or confused. In these states our mind is unlikely to be clear. Thus we may make the wrong decision or do the wrong thing. Students were able to state that, like the muddy water being stirred, their anxious mind cannot "see" things clearly. When asked what they would do, the common response was to keep cool or calm and let their minds "settle" down. (See sample responses in Annex B).

Table 3. Lesson 3 on "Reactivities of Weak and Strong Acids"

Lesson Information	Reversed Analogue	Reversed Target
Students: 30 Secondary 2 Lower Secondary Science Express stream students Cognitive domain: To compare the reactivities of a weak acid (vinegar) and a strong acid (hydrochloric	The emphasis in the cognitive domain was to help students identify the differences in the rates of reaction between an acid (weak or strong) with a piece of magnesium ribbon. (See worksheet in Annex C).	The emphasis in the affective domain was on the importance of being frugal and to save for rainy days. Students were able to identify their spending habits with that of weak acid reaction (slow, and some magnesium ribbon

acid) by reacting the acids with magnesium ribbons of equal lengths. Affective domain: Being frugal and to save for rainy days (a positive value and habit) Activities: Teacher talk, laboratory experiment and completing a worksheet with questions on the characteristics of weak and strong acids, followed by a reflective task on how fast they spend their monthly allowance given by their parents.	Students would be able to observe that in the strong acid (with the same amount and concentration as the weak acid) the magnesium ribbon is used up very quickly. For the weak acid, reaction is slower and often, given the same reaction time as for the strong acid, there is some magnesium ribbon left behind when the reaction is stopped, for example by draining away the acid.	may be left behind when they stop the reaction at the same time as the strong acid) or that of the strong acid reaction (fast, and the magnesium ribbon is soon used up). While there is no right or wrong answer to spending money in a fast or slow manner, a common comment that surfaced was that spending money wisely and saving money are only possible if they are frugal (that is, buy what they need and have a savings plan). (See sample responses in Annex C).

Observations and Results

As this paper is not a research report but a sharing on an exemplary teaching method, the results shared here are not meant to be based conclusively on empirical evidence. However, from the observed student responses in all three lessons, we may conclude that the use of this cognitive-affective integrative teaching approach is potentially helpful in getting students to be more aware of the important values, positive social habits and effective life skills while they are learning school science.

In the first lesson on “Reactivity of Potassium Metal”, the learning experiences were reported to be refreshing to both teacher and students. The teacher was able to use the opportunity of a science lesson to draw a parallel to the danger of having an uncontrolled emotional outburst (much like the uncontrolled explosive reactive behavior of the metal potassium when in contact with water). Students’ responses to the reflective task showed that they were able to surface the intended affective learning messages (see Annex A).

In the second lesson on “Separation Technique: Sedimentation” the teacher demonstrated before the class the differences between the characteristics of two samples of sand and water mixture by showing a sample of a muddy water that was allowed to settle overnight and another sample that had just been stirred. With the use of effective questioning skills, the teacher reported active participation among the secondary three students. The students' responses to the worksheet task were also appropriately related to how anxiety and confusion may be effectively managed and overcome (see Annex B).

In the third and final lesson on "Reactivities of Weak and Strong Acids" it was found, from the students' and teacher's reflective responses, that this laboratory-based learning experience did help raise the students' awareness of their spending habits and the importance of being frugal in the way they use their living allowances provided by their parents (see Annex C).

Recommendations

Students' reflective responses and feedbacks from the participating teachers, the results of these lesson trials, show a great potential in the use of "reversed analogies" to teach values and life skills to students.

The benefits that may be derived from using "reversed analogies" to surface values and life skills include the following:.

a) The optimal use of time to teach in the affective domain. The teacher completes the science lesson as usual and then continues with the reflective activities for students to surface values and skills. The reflective activities usually take only between five to ten minutes of class time;
b) Students get to identify the affective messages (the values or life skills) on their own by trying to see a parallel between these messages and the science concepts or skills they had just learnt. This can lead to ownership of learning and hence provide what one teacher termed as the "stickiness" of the affective message in their mind, especially when they need to associate that value or life skill later on in their lives;
c) Teachers are less likely to be burdened by a responsibility to teach values and soft skills explicitly. Explicit teaching of values may make teachers feel awkward, especially if students think of teachers as doing some form of "propaganda spreading".

However, there are also limitations in using this strategy of "reversed analogies". These include:

a) Not all science topics can be used as appropriate "reversed analogues". Only some topics lend themselves well to explain or describe a value or life skill;
b) There is a real concern that some students may become confused by the use of the reversed analogies and these could lead to the development of misconceptions, or worse, wrong conceptions of science facts and skills.

While the benefits do outweigh the limitations, teachers who intend to employ similar "reversed analogy" strategies in teaching of science within the cognitive and affective domains may be reminded of the following:

a) They have to ensure that the science concepts or skills taught are correct, accurate and appropriate before using these as the "reversed analogues";
b) They should frequently share and discuss their ideas and teaching plans with experienced teaching professionals and document their teaching experiences in personal professional teaching journals so that refinements and improvements to these "reversed analogies" could be made and used in future lessons.

Conclusions

Using the "reversed analogy" strategy may help make teachers become more confident and have a greater passion to help students understand the importance learning science in both the cognitive and affective learning domains. Since values and life skills are gaining importance, the cognitive-affective integrative approach to teaching science may possibly provide a lead to answering the question "How can we teach and prepare the younger generation to be that effective 21st century worker-citizen with an inquiring mind and a compassionate heart?"

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Annex

A Lesson 1: Review questions - Chemical Reactions (Sec 4NT)

Chemical Reaction

1. After viewing the experiment on the video clips, which experiment produces a more violent reaction when the metal was thrown into the beaker of water?

   ____

2. Potassium reacts with water vigorously/explosively but iron reacts very slowly with water.

   These examples can be likened to situations when others throw abusive comments or tease us in order to lure us into a fight or quarrel. We can impulsively fight back or we can remain calm and not be drawn into a fight.

   a. Which metal - potassium or iron, do you think best describes your emotional reaction when you are being verbally abused or teased?

   ____

   b. After potassium has reacted, the reaction mixture is hot and becomes a very strong (caustic) alkali because potassium hydroxide is produced.

   If your emotional reaction is like the way potassium reacts, describe briefly what may happen to you or your loved ones after you have been involved in a fight or an uncontrolled quarrel with someone else.

   ____

   ____

3. The reactivities of sodium and potassium metals can be controlled by putting them in oil which separates them from air.

   Think of a situation in which some people you know had a heated argument. How did you, borrowing the idea of sodium/potassium in oil, stop their quarrelling?

____

____

MESSAGE: We should control our emotions, especially in the event that others are challenging us to a quarrel/fight. It is always good to have someone (acting like oil) to separate us from them, thus preventing a possible fight that may result in injuries.

Sample student responses:

If your emotional reaction is like the way potassium reacts, describe briefly what may happen to you and your loved ones after you have been involved in a fight or an uncontrolled quarrel with someone else.	Think of a situation in which some people you know had a heated argument. How did you, borrowing the idea of sodium/potassium in oil, stop their quarrelling?
You will feel angry, mad like you want to ~~explode~~ explode yourself	Give them space and don't ~~too~~ not involve in a fight or quarrel
Our relationship may not be the same like last time and we may be bit by bit apart from each other.	I' think I will separate both of them and tried not to ask them to communicate with each other first for time being.
Would feel ashamed as we make our loved ones to involve in a fight	By asking them to talk calmly
My loved ones may be disappointed in me	I would separates to prevent them from fighting
My ~~pa~~ loved ones will be sad and angry too and I will cause them trouble and they will be involved in my matter.	Ask them to cool down and talk ~~with~~ calmly

B Lesson 2: Activity on separation techniques (Sec 3 Express)

Sedimentation

1. You are provided with two mixtures:

   Mixture (A): Sand and water which was shaken and left to stand overnight.
   [On teacher's bench. Please do not touch or disturb the container.]
   Mixture (B): Sand and water in a similar container.
   [Given to you with the cap tightened. Please do not open the container. Check that the cap is firmly tightened before you proceed with activity.]

2. Observe Mixture (A) and write your observation in the table provided below.

3. Now shake Mixture (B) gently by swirling the container until a suspension is formed.

4. Observe Mixture (B) after you have shaken the container and placed it on your bench. Then write your observation in the table provided below.

5. Compare your observations on these 2 mixtures below:

Mixture A (left standing untouched overnight)	Mixture B (which you have just shaken/stirred)
	

6. Why is Mixture (B), when shaken, often referred to as a suspension but not Mixture (A)?

____

____

7. By allowing the mixture to settle, sand can be separated from the water. Suggest another method by which sand can be separated from water.

____

Reflection

1. If you have a quarrel with your best friends, which of the two mixtures [Mixture (A) or Mixture (B)] would represent your emotion (or confusion)?

____

2. You would have observed that by allowing the shaken Mixture (B) to stand untouched for some time it will soon appear to look like Mixture (A).

   Using this observation, suggest how would you attempt to deal with your emotions (or confusion) in the situation where you had been quarrelling with your friends.

   ____

   ____

   ____

Sample student responses:

(1) If you have a quarrel with your best friends, which of the 2 mixtures [(A) or (B)] would represent your emotion (or confusion)? All responded to question (1) with “Mixture B”.
(2) You would have observed that by allowing the shaken Mixture (B) to stand untouched for sometime it will soon appear to look like Mixture (A). Suggest how you would attempt to separate your emotion (or confusion) in the situation when you have been quarrelling with your friends.
I would leave myself alone to cool down and soon my mood will stop changing easily. Things will become easier to see too. “I would leave myself alone to cool down and soon my mood will stop changing easily. Things will become easier to see too.”
I would cool down and try to make things right.
I will calm down and talk to them about the problems.
Walk away and let myself cool down for sometimes.

I will go to my room and calm down myself first.

C Lesson 3: Reactions of weak and strong acids (Sec 2 Express)

Aim: To compare the reaction characteristics of weak and strong acids.

Apparatus & materials: Hydrochloric acid, ethanoic acid, magnesium ribbon, test tubes.

Procedure:

1. (a) Pour 3 cm3 of aqueous hydrochloric acid into test tube A.
   (b) Pour 3 cm3 of aqueous ethanoic acid into test tube B.
2. Put in a piece of magnesium ribbon into test tube A, then observe.
   (a) Record your observations.
   (b) Insert a burning splint into the mouth of the test tube. A 'pop' sound indicates that the gas produced is **hydrogen**.
   (c) Repeat steps 1 and 2 for test tube B.

Observations:

1. Describe what happen when the magnesium ribbon is added to hydrochloric acid.

   ____

   ____

2. Describe what happens when burning splint is introduced.

   ____

3. Which solution is a weak acid? Hydrochloric acid or ethanoic acid?

   ____

4. Is the action of weak acid more vigorous or less vigorous than the action of strong acid?

   ____

Conclusion: Complete the following word equation

Therefore, Acid + ____________________ à Salt + ____________________

The following are some expected observations from the experiment with hydrochloric acid, a strong acid and ethanoic acid, a weak acid (the same volume being reacted with a fixed length of magnesium ribbon).

Observation within same time frame (say 5 minutes)	**Strong acid**	**Weak acid**
Rate of bubbles produced (visual inspection)	fast	slow
Amount of gas evolved	more	less
Amount of solid reactant used up	more	less

1. If the magnesium ribbon represents your monthly allowance (say S$300/-) would you consider your spending habits to be similar to the reaction characteristics of the strong acid or the weak acid?

___

2. Explain your daily life experiences based on your answer in (1).

___

3. Do you think this is an important value to embrace, or habit to practice in life? Why?

___

4. Do you think your habit will help you in times of emergency?

___

Sample student responses:

If the carbonate/magnesium represents your monthly allowance (say $300/-) would you consider your spending habits to be similar to the reaction characteristics of those of the strong acid or the weak acid? From your answer in (1), what value or habit would you be able to relate in your daily life experiences?	Do you think this is an important value to embrace or habit to practice in life? Why?
strong acid I (am not good)[1] at saving money	Of course not. When in times of crisis and I need money but do not have it, then I'd regret it.
weak acid I will usually calculate how much should I spend a day and put the rest of the money away for savings.	I think that it is a habit to practice in life and an important value to embrace because we should always save some money in case of financial trouble.
Strong Acid! I spend a lot of money because I eat a lot	Yes. We should eat more while we can
Weak acid I spend lesser money and save more	Yes. So I can save for my future
Strong acid. I spend money very quickly and Im very impatient.	Yes, I should learn to save money and be more patient.
strong acid as I think that I'm a spendthrift whenever I get my allowance. I am also very impatient. I believe that there is no point in wasting time as efficiency is good.	I think that it is quite important to have efficiency as it does not waste precious time, which can be used for other things. Getting the work done as fast as possible would be efficient.

[1] Student response has been edited by first author for the purpose of replacing student's original word with a similar and more appropriate phrase.