

## SHALL WE CONTINUE TO TEACH THE CANDLE BURNING EXPERIMENT AT LOWER SECONDARY LEVEL?

**Harkirat S Dhindsa**

*Department of Science and Mathematics Education  
Universiti Brunei Darussalam, Brunei Darussalam*

*The candle burning experiment is usually conducted in lower secondary classes to prove the (about) 20% oxygen in air. The aim of this paper is to show that teachers misinterpret the results of the experiment to satisfy the objectives of teaching this experiment. However, when the results of this experiment are interpreted correctly, the objectives for conducting this experiment at this level are not satisfied. It is therefore proposed that this experiment is not suitable at this level and should not be taught at this level. Teaching this experiment to meet the desired learning outcomes is a waste of time and adds to misconceptions. However, the simple experiments reported in this paper may be used to develop critical thinking and creativity in secondary school students. Further research in identifying pieces of knowledge for which similar mismatches between factual (scientifically accepted) and actual (misinterpreted results) knowledge claims is recommended.*

### INTRODUCTION

Content is an integral part of the science curriculum and its selection is determined by the objectives. A harmony between content, objectives and methodology is essential to teach the content effectively and fruitfully to students. Recent reforms in curriculum studies research have concentrated on the effectiveness of teaching methodologies in achieving the objectives (Dhindsa & Anderson, 2004; Garner, 1990; Hewson, & Hewson, 1983; Novak, 1990; Smith,

Blakeslee, & Anderson, 1993; Wandersee, 1990). In contrast, the curriculum reform movement in the 1960s and 1970s mainly concentrated on the renewal and updating of the content of science. Consequently the early research in the science education field was with related subject matter related that involved the selection of concepts, skills to be taught, and their sequencing in the curriculum. This is now treated as a dimension of science education research which is concerned with the scientific aspect of science education (Kempa, 1995). Kempa (1995) classified the subject matter (content) dimension into four categories (a) analysis and appraisal of the content of science, (b) selection of skills and concepts to be taught, (c) development of new approaches to teaching different concepts and (d) development of novel learning experience and experiments. A sustained interest in research in this area is demonstrated by changes or proposed changes to syllabus (Brown, 1997; Fensham (2002). For example, Fensham (2002) proposed the inclusion of the impact of forces on flexible bodies (skeletons) because of human accidents in industrial settings. The association between the outcomes of teaching selected content and the objectives however remains an area of study receiving inadequate attention.

Science is the human explanation of phenomena occurring within, and without humans. These explanations are dynamic in nature and change over time (Espana, & Salmorin, 1997). The change could be partial or complete modifications to our existing understanding. The societal developments also influence the social needs and thus the objectives of teaching and learning. These changes might create a mismatch between the objectives and content if not adjusted according to the changes. These changes therefore, highlight the need to evaluate an association between the content taught and the objectives for teaching it. The literature shows that over time the changes to content are slow as compared to changes in objectives. For example, Millar and Osborne (1998) stated that although all agree that the educational context and the need of

science is quite different from what it was in the 1960s, the best efforts of the 1990s have still retained the content of the 1960s as the science curriculum for this new situation. Gilbert (2005) stated that we are still teaching antique content. Moreover, despite research reports that highlight only with less content can better quality learning be achieved (Eylon & Linn, 1998), the school science curriculum is overcrowded and traditionally structured (Fensham, 2002). The long list of a traditional science content and the way it is structured so that is impossible for teachers to complete it in the specified time, may be the way traditional experts see modern society. It is believed that there is a significant fraction of non-essential science content taught in schools because it may not demonstrate a fruitful association between what and why we are teaching a specific piece of content. In some cases modifications to content knowledge do not flow down to where it is taught, in other cases the content knowledge is treated as simple, therefore, inaccuracy in its interpretations is not investigated. The candle burning experiment is an example which is treated as a very simple piece of knowledge and little work has been done to evaluate the accuracy of the interpreted results. The teaching of such topics is not only a waste teachers' and students' time, but also adds misconceptions to students' understanding. Moreover, the presence of such pieces of knowledge in the syllabus might influence the overall sequence in which the content is taught to reduce its effectiveness. If the objectives in the curriculum and places of these pieces of knowledge are revised, the revised desired aims might be achieved more fruitfully.

In this study the association between the objectives of teaching an experiment, "A candle burning in an inverted jar in a trough of water" and the knowledge claims based on the results of this experiment are explored. This experiment is conducted at lower secondary school level to demonstrate that oxygen content in air is about 20% and other conclusions are also drawn on (a) why a candle

is put out and (b) why water does rise in the jar. Dhindsa (2005) reported that teachers and students have misconceptions about the outcomes of this experiment. They appear to misinterpret the results (actual knowledge claims) of this experiment to make it meet the learning objectives. However these knowledge claims are not factual. Inconsistencies in the experimental results have been mentioned. For example, Hodkin (1995) attached a long live candle to the base of a desiccator and placed a mouse in the desiccator before closing it with the lid. He claimed that the candle is *probably* 'drowned' in the carbon dioxide that collects at the top of the jar and the mouse is far below to experience the effect of carbon dioxide. He is not sure about the results and also the hot to cold gas currents generated inside the desiccator are not accounted for. However, a systematic quantitative study involving this experiment has yet to be reported.

## **AIM**

The aim of this study was to develop some simple experiments to evaluate associations between objectives, actual knowledge claims and factual knowledge claims pertaining to the candle burning experiment. The actual knowledge claims deal with how the results of the candle burning experiment are interpreted and the factual knowledge claims deal with how the results of the experiment should be interpreted.

## **METHODOLOGY**

### **Experiment**

Take a trough and attach a candle to its base. Add a reasonable amount of water to the trough (depending upon the size of the candle). Now light the candle and then place an empty inverted jar over the candle so that its open end is immersed in the water. In seconds the candle is extinguished. Water rises in the jar.



## Major Objective

- To demonstrate that air contains about 20% of oxygen.

### Interpreted Results – Actual Knowledge Claims

- Oxygen in the jar is all consumed.
- Absence of oxygen in the jar puts the candle out.
- Water rises to take up the space (partial vacuum) created by consumed oxygen.
- Carbon dioxide dissolves in the water to create the space (a partial vacuum) to help water rise in the jar.
- Since water rises to take up about 20% volume of the jar therefore the experiment proves the presence of 20% oxygen in air.
- Since there is 20% oxygen in the air, water will rise to the same level irrespective of the number of candles lighted in the jar.

### Experiment Conducted to Evaluate the Above Actual Knowledge Claims

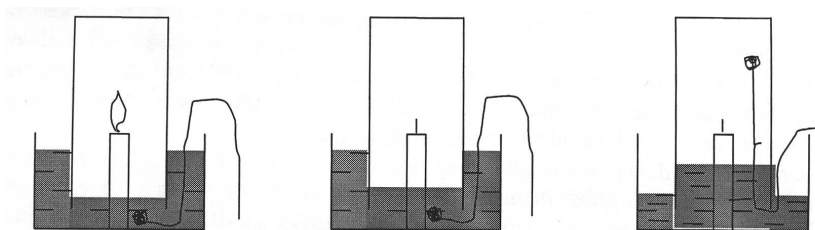


Figure 1: Testing the presence of oxygen with yellow phosphorus

*Experiment 1: Is the oxygen fully consumed?*

Take a trough and attach a candle to its base. Add a reasonable amount of water to the trough (depending upon the size of the candle). Transfer a small piece of yellow phosphorus into the trough. While keeping the yellow phosphorus under water, tie the phosphorus to an end of a thin flexible wire. Leave this end close to the candle. Now light the candle and then place an empty inverted jar over the candle so that its open end is immersed in the water. Wait till the candle is extinguished. Now one can test for the presence of oxygen in the jar using the following experiments.

- (a) Yellow phosphorus test: Slowly move the wire to raise the yellow phosphorus above the water inside the jar and observe (Figure 1). If it gives white fumes, the presence of oxygen is confirmed after the candle was extinguished. Yellow phosphorus does not react with carbon dioxide.
- (b) Living insect or animal test: Hold a grasshopper in your fingers. Tilt the jar slightly without exposing its open end to air and push the grasshopper (or a small mouse) in the jar. It will quickly get out of water and most likely rest on the wall or on the candle and observe. Observe if the living organism survives for a considerable time to verify the presence of oxygen.
- (c) Rusting test: Attach some clean iron wool at the closed end of the jar and make it wet before the jar is inverted on the candle. Keep it overnight or for the weekend and observe: if the iron rusts oxygen is confirmed.

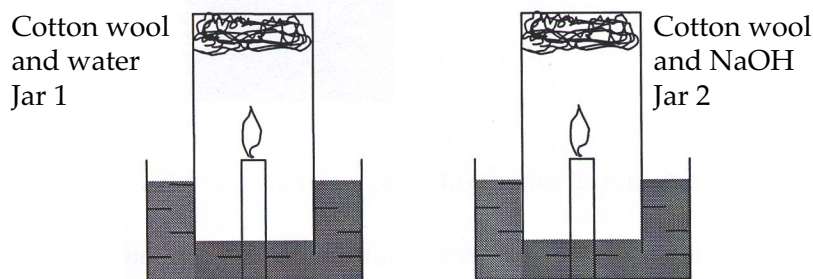


Figure 2. Removing  $\text{CO}_2$  with NaOH

*Experiment 2:* Is it the presence of carbon dioxide or the absence of oxygen that puts the candle off?

Figure 2 shows the arrangement for this experiment. Take a trough and attach a candle to its base. Add a reasonable amount of water to the trough (depending upon the size of the candle). Fix equal amounts of cotton wool inside to the closed end of the two identical gas jars. Spray the cotton wool in one jar with water and the other with NaOH solution. Use approximately equal amounts. Now light the candle and then place the inverted jar containing the cotton sprayed with water over the candle so that its open end is immersed in the water. Record the time it takes for the candle to extinguish itself and the level to which the water rises in the jar. Now repeat the experiment using the jar with cotton sprayed with NaOH. Repeat these experiments 3 times and compare the mean time the candle burns and the volumes of water rise in the two jars (with water and NaOH). Using this data make a conclusion what puts the candle out. Also test the presence of oxygen in Jar 2, using the yellow phosphorus test.

*Experiment 3:* Is the ratio of carbon dioxide to oxygen important in determining the burning of a candle?

Take a trough and attach a candle to its base. Attach two long rubber tubes to the candle (or simply attach these to the jar) in such

a way that their open ends are above the water level and the other ends outside the trough (Figure 3). Add a reasonable amount of water to the trough (depending upon the size of the candle). Now light the candle and then one student should place an inverted jar over the candle so that its open end is immersed in the water and another student inhales the air without sending it to his lungs and starts blowing slowly air into the jar through a rubber tube A. Observe the burning time for the candle. The student who is blowing air into the jar has to stop to breathe for some time. If he stops say for about ten seconds to take a breath, observe what happens to the burning candle. Record your observations. (Rubber tubes are convenient, however, other similar arrangement could be made).

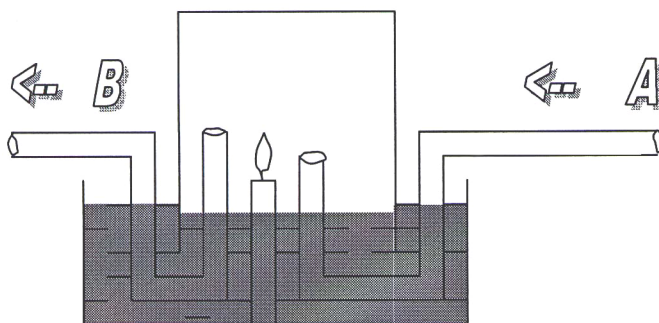


Figure 3: Arrangement for blowing air into the jar to remove smoke and air mixture

*Theoretical calculations.* Does the candle burning in the jar create an empty space (a partial vacuum?)

A general hydrocarbon combustion equation is used to compare the moles of gas-phase reactants and products. The composition of wax is complex, but for the sake of teaching, this procedure is adopted.

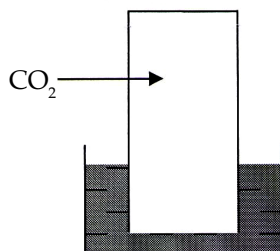


Figure 4: Testing the solubility of  $\text{CO}_2$

*Experiment 4:* Is it the solubility of carbon dioxide in water that supports the rise of the water?

Generate some carbon dioxide by reacting  $\text{HCl}$  with  $\text{CaCO}_3$ . Now fill the gas jar with carbon dioxide by downward displacement. You may test if the jar is full by bringing a burning splint at the mouth of the jar. Cover the jar with a glass cover and invert it in a trough of water and observe the extent of water risen (Figure 4). Record the mean volume of water risen in the jar in ten seconds, one minute, 20 minutes and for overnight. Fill two more gas jars with carbon dioxide and repeat the above procedure.

*Experiment 5:* Comparing the effects of using one, two and three candles in this experiment.

Take three identical candles, heat them together to an assembly and then attach the assembly to the base of a trough (Figure 5). Add reasonable amount of water to the trough (depending upon the size of the candle). Now light one of the candles in the assembly and then place an inverted jar over the candles so that its open end (the jar) is immersed in the water. Record the time it takes for the candle to extinguish and the level to which the water rises in the jar. Repeat the above experiment three times and find the mean time and compute the mean volume of the jar occupied by the water. Repeat the above experiment by lighting two and three candles.

Compare the mean candle burning time and the volume of water that has risen. Make sure you subtract the volume of the candle assembly to calculate the volume of water that enters the jar.

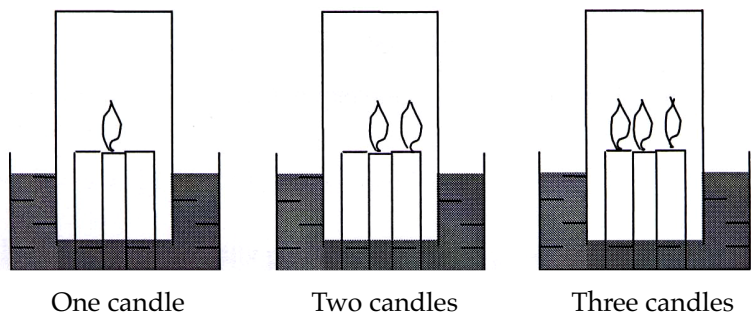


Figure 5: Using 1, 2 and 3 candles in the experiment

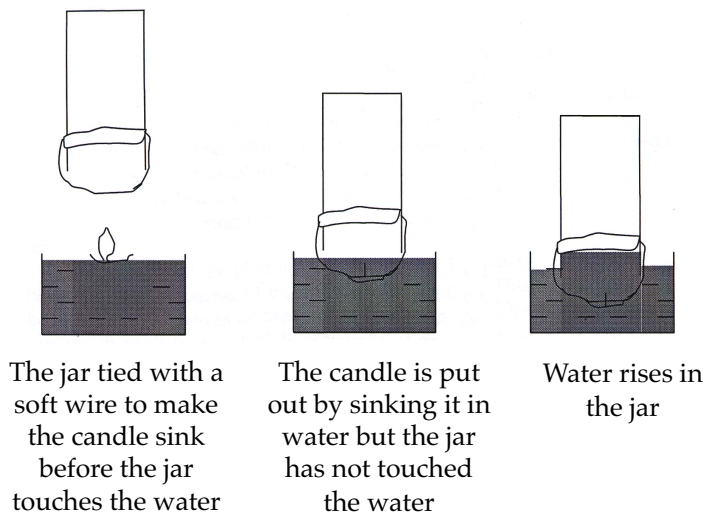


Figure 6: Testing the effect of thermal expansion on air in the jar prior to the candles starting to burn in the jar

*Experiment 6:* Does the air in the gas jar expand and leave the jar before the jar touches the water in the trough?

Take a trough and add a reasonable amount of water to the trough. Now take a small candle with an aluminum cup or attach a small candle on a cork so that the candle floats. Tie a soft wire at the open end of the jar to use it for making the candle sink in water to extinguish it before the jar touches the water (see Figure 6). Now invert the jar on the candle so that you extinguish the candles by sinking it in water before the jar touches the water. In this case the candle did not burn in the jar. Push the jar downward to dip its open end in the water. Now observe the water rising in the jar. One may use another means to extinguish the candle to create the condition described in the jar. This experiment was also tried by tying two strings to the aluminum cup of the candle and then running over the trough. When the jar was lowered, it pushed the sting down and made the candle sink.

## RESULTS

The results for the above-stated experiments and the theoretical calculations are reported under this heading.

*Experiment 1:* Is the oxygen fully consumed?

**Yellow phosphorus test:** Yellow phosphorus when pushed above the water level in the jar after the candle was put out, gives white fumes. These white fumes are obtained when phosphorus reacts with oxygen. It does not react with carbon dioxide as it is prepared under the atmosphere of carbon dioxide (Holderness & Lambert, 1984). The presence of oxygen in the jar even after the candle was put out was therefore established.

**Living insect or animal test:** The grasshopper survived for a long time. The experiment was repeated with a small mouse that too survives for a reasonable time. The living organisms were removed

after students accepted that the oxygen is present even after the candle was put out, to avoid undue stress on them. This experiment confirmed the presence of oxygen in the jar after the candle was put out.

Rusting test: The iron wool rusted. The rusting of iron wool indicates the presence of oxygen in the jar after the candle is put out.

All the above experiments support the presence of oxygen after the candle in the jar was put out. The presence of oxygen can be tested by using an oxygen sensor. The sensor could be attached inside the jar before it is inverted on the burning candle. These experiments do not support the actual knowledge claims taught by teachers to their students.

If the oxygen in the jar is not depleted why does the candle extinguish itself? The basic explanation given is the absence of oxygen puts the candle out. This explanation is not true as the above experiment proves the presence of oxygen in the jar after the candle is put out. It may be worth considering a new hypothesis that the oxygen level drops to a limit that will not support the burning of a candle in the jar. To investigate this hypothesis, Experiment 2 was conducted.

*Experiment 2:* Is it the presence of carbon dioxide or the absence of oxygen that puts the candle out?

Carbon dioxide reacts with sodium hydroxide to produce sodium carbonate. Therefore, the presence of cotton wool sprayed with sodium hydroxide will remove carbon dioxide. If the level of oxygen is too low to support a candle burning, the time taken for the candle to extinguish itself in both conditions (with water and with sodium hydroxide) should be the same. The mean data for this experiment is reported in Table 1.



Table 1

*Burning Time (Seconds) and Volume of Water Rise in Jars Containing Cotton Wool Sprayed with Water and Sodium Hydroxide*

Cotton wool sprayed with	Number of Measurements	Burning Time (s)		Volume of water rise in jar (%)	
		Mean	SD	Mean	SD
Water (Jar 1)	3	5.1	0.7	22.2	1.3
NaOH (Jar 2)	3	9.2	1.3	26.9	1.1

These results show that the candle burning time in Jar 2 (presence of NaOH) was much longer than in Jar 1 (presence of water). These results prove that there was enough oxygen in the jar to support the candle burning at the time it was put out. This experiment also indirectly proves that oxygen was not depleted during the candle burning as claimed in doing experiment 1 in the classroom situation. Moreover, the hypothesis that the candle was put out due to the too low level of oxygen in the jar to support burning is not supported by these data. The question here is that if the oxygen in the jar is enough to support the candle burning, then what puts the candle out? The data on the volume of water risen in the jar supports removal of carbon dioxide during the candle burning. The removal of carbon dioxide from the jar lowers the overall pressure in the jar and hence more water goes into the jar. Therefore, these results suggest that it is the presence of carbon dioxide in the jar that puts the candle out. The fire extinguishing properties of carbon dioxide are well known and it is used in fire extinguishers.

In this experiment carbon dioxide is removed using sodium hydroxide. The candle was again put out but after burning for a longer interval of time. What puts the candle out at this time: absence of oxygen or something else? This question was investigated by investigating the presence of oxygen in jar 2 after the candle was

put out using yellow phosphorus. White fumes were given out by the yellow phosphorus. These fumes support the presence of oxygen in the jar. Therefore, the oxygen is still not finished in jar 2. Based on the logic that a critical ratio of oxygen to carbon dioxide is required to put out the candle, it is believed that a similar ratio does exist between oxygen and nitrogen. Nitrogen gas also does not support combustion.

The results of these experiments which support the view that the presence of carbon dioxide puts the candle out add an additional question for verification. If carbon dioxide is responsible for putting the candle in the jar out, then is there a critical level of carbon dioxide that should be reached in the jar to put the candle out? The experiment 3 sheds some light on this question.

*Experiment 3:* Is the ratio of carbon dioxide to oxygen important in determining candle burning?

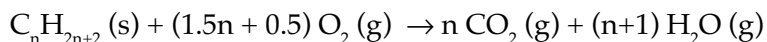
As long as the student was blowing air into the jar through tube A, the candle continued to burn, however when he/she stops to blow, the candle is put out. What happens in this process is that during the time the student continues to blow air in the jar, a mixture of air and the products of burning especially carbon dioxide go out through the other tube B. The level of carbon dioxide stays much below a certain critical level. When the student stops to blow, soon the critical level of carbon dioxide level is reached and the candle is put out. This experiment indicates that there is a critical ratio between carbon dioxide and oxygen; if that ratio is reached then the burning of candle is not supported. Other reactions with oxygen in the jar may still be possible as demonstrated in Experiment 1 (reaction with yellow phosphorus).

In summary, the above results suggest that during this experiment the oxygen is not depleted. If oxygen is not depleted, then the experiment does not prove that air contains about 20% oxygen. Moreover, the candle is not put out due to the absence or

the low level of oxygen achieved during burning but it is the carbon dioxide (or nitrogen if carbon dioxide is removed) responsible for extinguishing the candle. A critical ratio of oxygen to carbon dioxide (or nitrogen) plays a crucial role in extinguishing the candle. However, these experiments do not guide us to why water, despite being heavier than air, rises in the jar? Most teachers teach that space (vacuum) is created due to the complete burning of oxygen and the water rising in the jar to fill this partial vacuum. The following experiments and theoretical calculations help us understand the question maybe more clearly.

*Theoretical Calculations.* Does the candle burning in the jar create an empty space (vacuum)?

The nature of the products will depend upon the composition of the candle material. Let us assume that combustion of saturated hydrocarbons is taking place during burning. The following reaction should take place in general, but when the concentration of oxygen is lowered, some carbon monoxide may also be produced.



For  $n = 1$ , two moles of oxygen will react with a mole of  $\text{CH}_4$  to produce three moles of products (assuming a controlled supply of methane and the supply stops as soon as the flame is put out). The number of moles of the products is 1.50 times that of oxygen (reactants in the gas phase). As  $n$  increases, the multiple factor decreases from 1.50 and approaches 1.0, at  $n = \infty$ . For  $n = 30$ , a typical paraffin wax, the factor will be 1.34.

This means that burning actually increases the gaseous molecules in the jar and hence an increase in pressure inside the jar is expected. Therefore, burning does not reduce the volume to create the empty space (vacuum). Hence water being heavier than air should not rise in the jar due to burning as is taught by teachers. Some other factor(s) is (are) contributing to the phenomenon.

In the above equation, the phase of water is written as a gas, whereas most of the equations written in the books report it as a liquid. If one changes the phase to liquid, then certainly the number of moles should go down and the volume should be reduced for the water to rise in the jar. However, in this study it was not assumed so because the burning of the candle increases the temperature of the jar and the air in it. Even a few degrees rise in temperature should account for water vapour produced in a short time for which the candle burns as the saturated water vapour pressure rises with an increase in temperature. Water vapour pressure at 25°C and 28°C are 23.76 mm Hg and 28.35 mm Hg respectively (Aylward & Findley, 1994). However, it is good logic for students to discuss along these lines. Moreover, the author also believes that a fractional contribution towards a water level rise in the jar may be possible due to condensation of water vapour, but not to the extent one sees in the experiment.

In summary, the above calculations suggest that the water does not rise in the jar due to the depleting of the oxygen. Condensation of water vapour is not a major factor that could help the water rise in the jar in such a short time. Something else is responsible. The next experiment investigates the role of carbon dioxide solubility in water to help water rise in the jar.

*Experiment 4:* Does carbon dioxide dissolve in water to help water rise in the jar?

Our observation is that there is no rise in the water level for short times such as 20 minutes. All the carbon dioxide may not dissolve even in one day. The solubility of carbon dioxide in water is 1.45 g/L at 25°C and one atmosphere (Aylward & Findley, 1994). However, it will take a much longer time to reach this saturated condition unless carbon dioxide is bubbled through the water. The solubility rate of carbon dioxide is decreased as the acidity of water increases due to the dissolved  $\text{CO}_2$ . Based on the author's

observations and above carbon dioxide solubility data, it may not dissolve so quickly as to support the water rise in a short time as it takes to conduct the experiment. A negligible contribution based of theoretical possibility might happen but not the extent to which teachers think. Therefore, the claim that the water level rise is due to the solubility of carbon dioxide is not supported.

*Experiment 5: Effect of burning more than one candle.*

This experiment was conducted because teachers and students thought that air contains 20% of oxygen. Therefore, with an increase in the number of candles, the burning time should decrease but the amount of water that rises in the jar should be the same irrespective of the number of candles as air contains about 20% oxygen by volume.

Table 2  
*Burning Time and Volume of Water Rise for One, Two and Three Candles*

Number of candles	Number of Measurements	Burning Time (s)		Volume of water rise in jar (%)	
		Mean	SD	Mean	SD
1	3	5.8	0.9	23.2	0.30
2	3	4.5	1.4	27.8	1.38
3	3	1.4	0.3	34.3	2.87

The data in Table 2 show that the burning time decreased with an increase in the number of candles as teachers believed. However, the percentage of volume of the jar occupied by the water increased with an increase in number of candles. Therefore, the results of the experiments described in Table 2 are not in line with what teachers teach.

All the above experiments and theoretical calculations do not support the notion that this experiment proves that air contains about 20% oxygen by volume. In actual practice what really happens in this experiment is that lots of air escape from the jar during the

experiment which creates a space for the water to rise in the jar after the candle is put out. Incidentally, under the experimental conditions, i.e. the way the experiment is conducted, a rise of water level in the jar is close to 20% by volume. Experiment Six was conducted to verify this hypothesis and the results of the experiment supported this hypothesis.

Table 3  
*Volume of Water Rise Without Burning Candle in the Jar*

Number of Measurements	Volume of water rise in jar (%)	
	Mean	SD
3	13.2	0.87

*Experiment 6:* Does the air in the jar expand and leave the jar before the jar touches the water in the trough?

As soon as the jar touches the water surface the water starts rising into the jar. By using a very short candle the experiment demonstrates that about 13% of the water rises is possible when the candle did not burn in the jar. The percentage is expected to increase with an increase in candle height. This experiment proves that water rises due to something else than the space (partial vacuum) created due to the depleting of the oxygen in the jar as assumed by the teachers and students.

The explanation for the water level rising in the jar is that during burning, the smoke is produced which rises upward to a higher temperature compared to the surroundings. Along with the smoke hot air surroundings the flame will also rise upwards. The air current gives the candle flame a dome shape. The burning of candle is explained in details by Faraday (1860). As soon as the inverted jar is over the candle, hot air and smoke enter the jar. The air in the jar expands quickly and some of the air leaves the jar due to thermal expansion even before the jar touches the water. After the jar touches the water the air cools and air pressure inside is decreased. The decrease in pressure in the jar pulls the water up.

In the actual process, the rise of water is about 20%; the above experiment shows about 13% which may go up further with an increase in the height of the candle. But this still may not account for the 20%. During the initial phases of the experiment, when the candle is burning in the jar, bubbles of air escape through the water. The loss of air bubbles under this condition adds to the above 13% loss to account for the about 20% rise in water level.

After considering the results of the experiments and theoretical calculations reported in this study, it is worth revisiting the objectives of doing this experiment and to compare the actual and factual knowledge claims. The comparison is reported in Table 4. The data in the table show that none of the objectives have been met by conducting this experiment. Under these circumstances the suitability of this experiment for teaching to fulfill the listed objectives is discussed under discussion.

Table 4  
*Revisiting Objectives: Comparing Actual and Factual Knowledge Claims*

Actual Objectives	Objective achieved	Factual Objectives	Reference
Candle is put out when all the oxygen is depleted.	No	All oxygen is not depleted.	Experiment 1
Candle is put out due to absence of oxygen.	No	Presence of CO <sub>2</sub> to a critical ratio puts the candle out.	Experiment 2
Water rises in the jar to take up the empty space created due to the burning of oxygen.	No	Burning does not create the empty space to the extent that the experiment claims	Theoretical calculations

Water rises in the jar to take up the empty space created due to the dissolving of carbon dioxide in water.	No	CO <sub>2</sub> does not dissolve so rapidly. CO <sub>2</sub> contribution to the water rise is negligible.	Experiment 3
Water rises in the jar to compensate for a decrease in pressure due to the condensation of water vapours.	No	Water rises due to partial loss of air from the jar because of thermal expansion	Experiment 1
The rise of water in the jar does not depend on the number of candles. Water will rise to the same level as air contains 20% oxygen.	No	It does depend upon the number of candles. With more hot air and smoke, more air escapes from the jar in the beginning of the experiment.	Experiment 6
The experiment proves 20% of oxygen in air.	No	The experiment does not prove 20% oxygen in air.	Experiments 1, 4, 6

**DISCUSSION**

A question to answer is that if none of our objectives for conducting this experiment is fulfilled, shall we continue to teach it? The author believes it should not be taught because this piece of knowledge is misplaced in the curriculum. This experiment is conducted in lower secondary classes in most countries, however, in some countries this experiment has been moved to the upper primary level. It is never revisited at the secondary or tertiary levels. By teaching this



experiment at the lower secondary level to fulfill the listed objectives results in misconceptions for the rest of the life of the student (Dhindsa, 2005). The students and teachers already have many misconceptions about the concept of combustion, this experiment adds to their misconceptions (Boujaoude, 1991; Dhindsa, 2005; Gabel, Stockton, Monaghan, & Makinster, 2001). The experiments reported in this study show that the candle burning experiment involves higher-level science than students at lower secondary students can understand. The author believes that moving this experiment to the upper primary level as has been done in Singapore is a mistake.

When should we teach this experiment? The curriculum research emphasizes the need that curriculum should address the need of creativity, critical thinking and innovative forward thinking (Ng & Abdul-Rahman, 1997). The author believes that this experiment could be useful at upper secondary level to address the above-stated issue. The upper secondary students could be asked to plan and conduct experiments reported in this paper. These experiments could be useful in developing critical thinking and investigative skills in the secondary students and will involve them in developing simple experiments. At this stage they also might have insight of chemical reactions and shall be able to compare number of molecules (may be moles) in the reactants and products.

The conceptual change approach is a way of teaching students using constructivist theory (Linder, 1993; West, & Pine 1985). This approach highlights the importance of creating a cognitive conflict to make conceptual change. The experiments described in this study could be used for creating cognitive conflict to help students learn combustion in open and closed environments.

In this study, it is believed that all the carbon dioxide is removed by using NaOH. No doubt NaOH is a highly active reagent and reactions with  $\text{CO}_2$  is very fast, but an absence of  $\text{CO}_2$  was not

experimentally confirmed. Moreover, based on results it was interpreted that ratios of  $O_2$  to  $CO_2$  and  $O_2$  to  $N_2$  are important. However, the situation may be that ratio of  $O_2$  to all other gases present in the jar ( $N_2 + CO_2 + CO + H_2O$  vapours) may also be important. This hypothesis needs to be tested in future.

Is this the only piece of knowledge that is misplaced? The author believes it is not so. There could be many simple concepts that, accordingly to their present place in the curriculum, do not satisfy their objectives therefore leading to misconceptions. The author believes that the water cycle also taught at lower secondary is another one that needs attention. Hence, there is a need to conduct extensive research to find pieces of knowledge that need special attention.

## CONCLUSION

The candle burning experiment is often conducted at lower secondary level to prove mainly that air contains about 20% oxygen and the candle is put out due to absence of oxygen in the jar as all oxygen is used up during combustion. The detailed investigations reported in this paper suggest that the candle burning experiment does not support the objectives that are thought as being achieved by conducting it. More importantly by conducting this experiment teachers may transfer their misconceptions to students. These misconceptions never get modified as this experiment is not visited by the learner at a later stage. It is therefore important for the curriculum designers to re-evaluate this experiment and consider the appropriate stage suitable for this experiment to be taught. The author believes this experiment has a great potential for teaching critical thinking at secondary level. There is a need to identify other pieces of knowledge that need repositioning their places for effective teaching and learning. Moreover, there is a need to develop another simple experiment that could be used by teachers at lower secondary or upper primary levels to verify the percentage of oxygen in air.

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