# Michael Smith Science Challenge

# 2013

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Analysis

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## Introduction

The Michael Smith Challenge is a national science contest written by students in Grade 10 or lower. It was piloted in the province of British Columbia in April 2002, and has run nationally every year since. It is intended to spark enthusiasm in the many different fields of science among young Canadian students. The Michael Smith Science Challenge is the only nationwide competition covering all science subjects taught in grade 10/niveau 4. It is offered in English and French. This year, 1618 students (1000 times the golden mean!) participated in the contest on February 26.

## Design of the Michael Smith Challenge 2013

The exam consisted of 6 questions worth 10 points each. Many of the questions were very open-ended, producing a broad variety of answers. Chemistry, physics, biology, earth science, logical reasoning, and scientific argument were all covered in this year's contest.

Continuing the trend of recent years' contests, the 2013 contest placed an emphasis on testing students' logical and creative thinking with regard to science rather than their memorization skills.

## Registration & Participation

Teachers filled out a form on the Michael Smith Science Challenge website and submitted their name and school information, as well as their students' information. Registration opened on January 21st and officially closed on February 25th, the day before the contest. In the week before the contest, all registered teachers were emailed a password to access the contest on the contest day.

This year, 150 teachers from all 10 provinces registered for the contest, as seen in Figure 1. A total of 1734 students were registered (exactly the same as in 2012) and 93% of registered students participated in the contest.

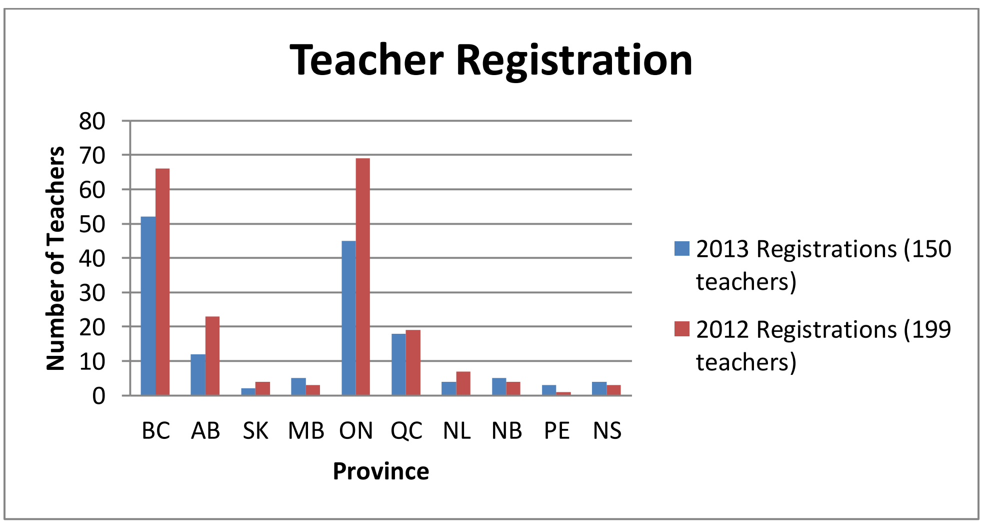


**Figure 1: Teacher participation by province in the 2013 and 2012 Michael Smith Challenges.**

# Results of the Michael Smith Challenge

## Overall

The average score was 28%, which is significantly lower than last year's average of 44%. This year's lower scores are due to the number of open-ended questions on this year's contest. Marks were allocated in no smaller than 0.5 point increments. There were no ties for provincial or national prizes.

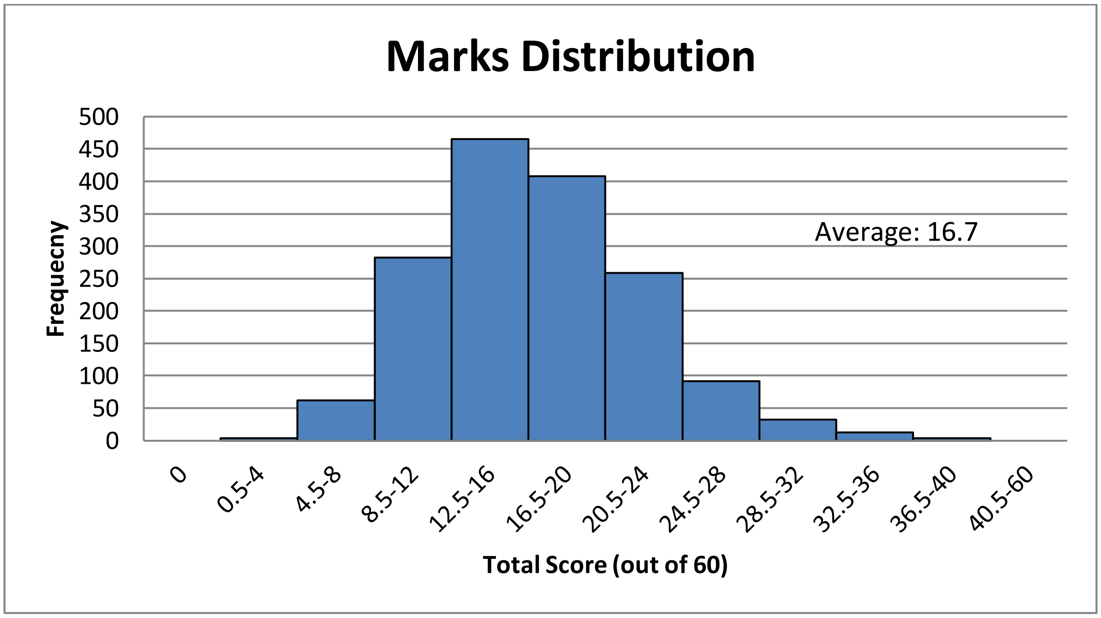


**Figure 2: Histogram showing the frequency distribution of marks. The highest mark achieved was 40 out of 60 and the average was 16.7 out of 60. No test received zero marks.**

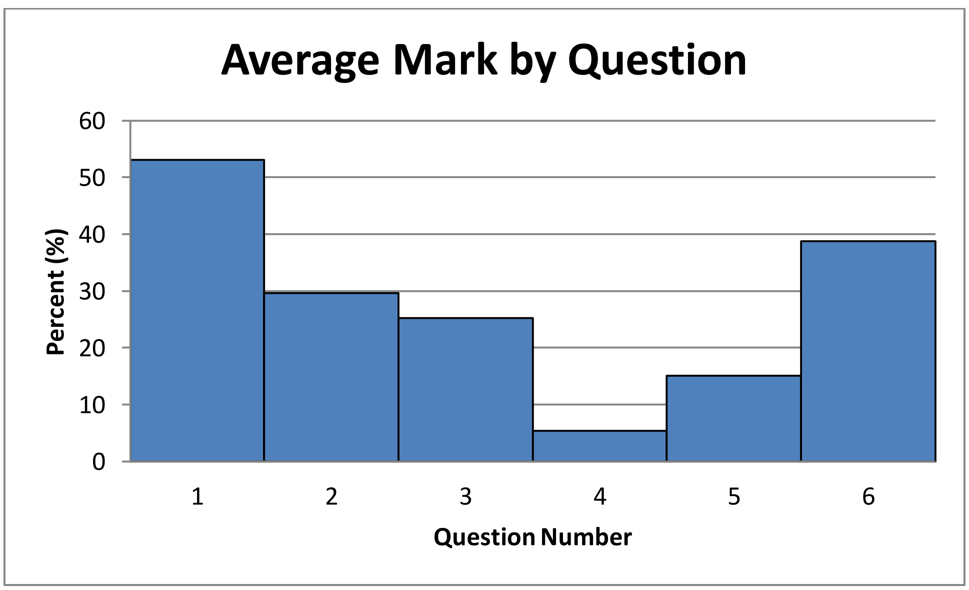


**Figure 3: Histogram showing the average score for each question.**

## Question 1

$H_2CO_3$ is an ingredient in pop that makes it carbonated, or 'fizzy'. It undergoes a decomposition reaction to produce the desired carbonation, or 'fizziness'.

a) Is $H_2CO_3$ an acid or a base?
   Acid

b) Fill in the missing product in the following decomposition reaction, and indicate the phase of each product.

   $H_2CO_3 \rightarrow H_2O(l) + CO_2(g)$

c) Explain why this reaction makes the drink 'fizzy' (50 words maximum).

   The fizziness of the drink is the result of $CO_2$ gas forming in liquid. The gas forms bubbles in the liquid which rise to the top of the drink due to the lower density of the gas. One can feel these bubbles popping when they hit the mouth. The decomposition reaction does not occur until the can is opened and the high pressure environment inside is released.

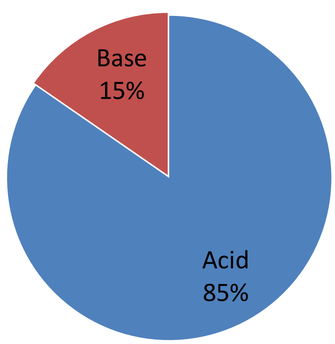


**Figure 4: Student responses to question 1.a)**

***Marking Scheme:***

***2 Marks:*** *a) Acid*

***2 Marks:*** *b) Missing product is $CO_2$*

***1 Mark:*** *b) $H_2O$ is liquid*

***1 Mark:*** *b) The missing product is a gas*

***1 Mark:*** *c) $CO_2$ is responsible for the fizziness.*

***1 Mark:*** *c) Production of a gas within a liquid will create bubbles/effervescence*

***1 Mark:*** *c) The bubbles rise because they are less dense than the liquid*

***1 Mark:*** *c) High pressure in the can prevents the decomposition reaction from happening until the can is opened*

***1 Mark:*** *c) Bubbles hitting or popping on the tongue creates the 'fizzy' sensation*

This question was intended to be the easiest one on the test, and indeed it had the highest average (53%) of the six questions. 85% of students correctly stated that $H_2CO_3$ is an acid, and 81% of students correctly determined the missing product to be $CO_2$. 50% of the students indicated the correct phase of each product in part b). This low fraction was likely due to hasty reading of part b), considering that many students neglected to mention phases in part b) but then went on to indicate the phases in their explanation for part c). Half of all students recognized that $CO_2$ bubbles were the cause of the fizziness, but less than 10% of students mentioned anything more about factors such as density, pressure, etc.

## Question 2

We all know that ice floats in water. Imagine if ice were denser than water. Consider how this would impact life on Earth. List up to five ways, no more than 30 words each.

***Marking Scheme**:*

***1 to 2 Marks:** A major point, depending on justification*

***0.5 Marks:** For each additional point which follows directly from a major point*

Some of the most common valid answers from students:

- Water would contract when it freezes
- No surface ice on oceans
- Animals and people accustomed to life near/on floating surface ice would have difficulty getting around
- Dark ocean water absorbs much more heat from the sun than white reflective ice, increasing Earth's albedo
- A warmer Earth could cause more ice melt, raising water levels
- The submersion of all previously floating ice would raise water levels
- Increased ice formation on seabeds/lakebeds tend to cause water levels to lower
- Bodies of water freeze from the bottom up
- Lakes freeze solid more easily with no layer of insulating surface ice
- Loss of seabed/lakebed habitat due to ice formation
- Fish egg laying process will be disturbed by ice formation
- No plants on seabed could reduce oxygen levels

This question naturally produced a very wide variety of answers. Some students considered a world where ice has always been denser than water, while the majority of students considered a world where ice all of a sudden became denser than water one day. Within the latter group of students there was a split between people who imagined the world's ice masses shrinking in order to increase density, and other people who imagined the world's ice masses getting heavier and staying the same volume. All of these interpretations were accepted. In some cases (like for the point about ocean levels), the students' interpretation of the question affected the validity of their answer. The most common answer (58% occurrence rate) was that animals and/or people accustomed to life near/on floating surface ice would have difficulty getting around.

## Question 3

There are two competing hypotheses (A and B) that attempt to explain the same phenomenon. A scientist performs an experiment to see which, if any, is right, and makes a series of measurements shown below. Hypothesis A predicts an outcome of 100, while hypothesis B predicts 200. What would you conclude about the validity of these two hypotheses?

| |
|---|
| **95.5** |
| **93.7** |
| **116.9** |
| **89.4** |
| 195.3 |
| 209.3 |
| 202.4 |
| **97.9** |
| 191.4 |
| 185.0 |
| 214.0 |
| 190.9 |
| 200.7 |
| 198.0 |
| **91.5** |
| **119.5** |
| **80.2** |
| 213.8 |
| **99.8** |
| **104.8** |

Half of the data (bolded) clumps around 100 while the other half of the data clumps around 200. There are no data points around the average of the data, 149.5. This bimodal distribution suggests that there may be some uncontrolled variable determining the outcome of the experiment. There is no reason to consider one hypothesis more valid than the other with the given information. A complete hypothesis could combine hypotheses A and B.

***Marking Scheme:***

***4 Marks:*** *Data clumps around the values 100 and 200 (bimodal distribution).*

***3 Marks:*** *Mentioning an uncontrolled variable*

***2 Marks:*** *Suggesting the presence of some systematic error in half of the measurements (only 1 mark if the student already mentioned an uncontrolled variable)*

***2 Marks:*** *Saying that a complete hypothesis would have to include both of the outcomes*

***1-2 Marks:*** *Stating that not enough information is given, or that an expected range needs to be given, e.g. 100+/-10, or that units are needed*

Question 3 had the most spread out scores out of all of the questions, having a standard deviation of almost 2.5 marks. Students who did not recognize the clumping typically received only 1 or 2 marks at the most, while students who did recognize the clumping had the opportunity to score much more points by drawing conclusions from their clumping observation. See figure 5 on the following page for a breakdown of how students responded.

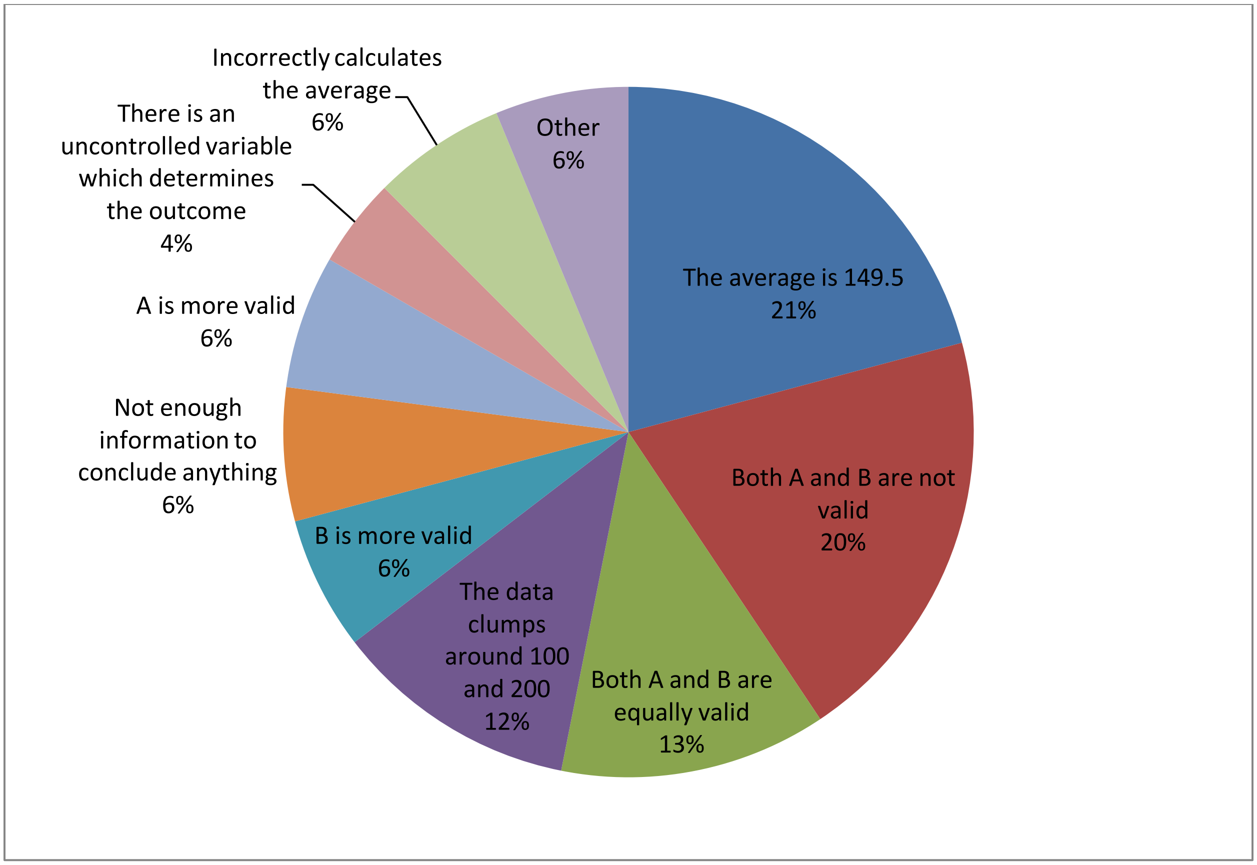


**Figure 5: Analysis of student responses for question 3. Students averaged 2.5/10 for this question.**

## Question 4

It was once believed that the planets, the Sun, and other stars all revolved around the Earth. This was a generally accepted 'fact' based on the observation that these bodies do appear to move around the Earth every 24 hours. However, we now recognize that the Earth rotates about its own axis. How do we know? List up to three reasons, no more than 30 words each.

***Marking Scheme:***
***Up to 4 Marks:** Major point. Mark depends on the extent to which the point is explained.*

- The Coriolis effect causes large scale air and ocean currents. This phenomenon is responsible for our weather patterns (direct evidence).
- The Foucault pendulum (direct evidence).
- Retrograde motion of the planets (very convoluted explanation if Earth doesn't rotate).
- Earth's magnetic field (we would not have one without the Earth's rotation, but needs dynamo model)

Question 4 was the most difficult question for students, with 85% of students receiving zero marks, resulting in an average mark of 5%. The most common response was to list *consequences* of the Earth's rotation (e.g. 24 hour daylight cycles) rather than *proof* of absolute rotation. The most common answer was the seasons, which is indirect evidence and could be explained by the movement of the Sun around the sky without the Earth rotating. The distribution of answers is shown in figure 6. The category 'other' includes all responses with 2% frequency or less. The Foucault pendulum (the most direct *prima facie* evidence of the Earth's absolute rotation) was mentioned by three students.

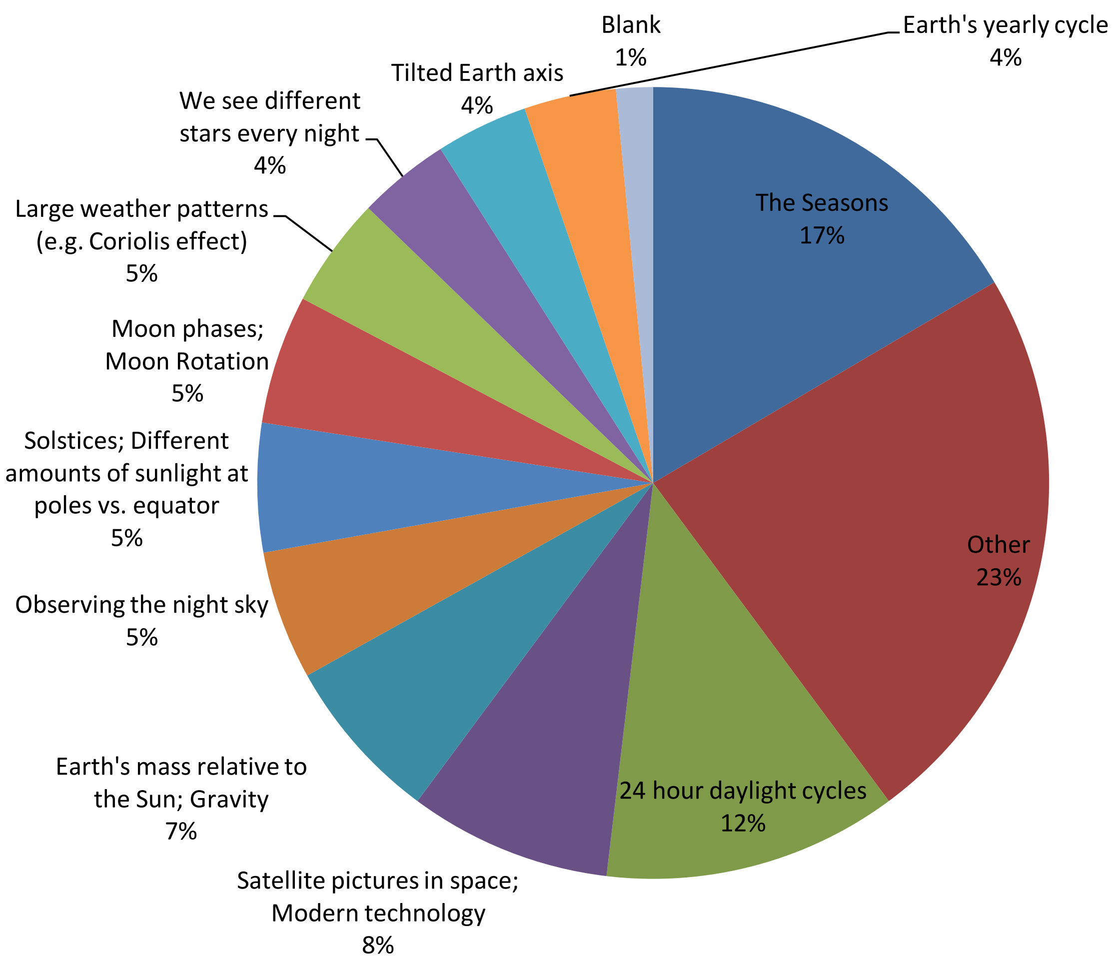


**Figure 6: Analysis of student responses for question 4. Students averaged 0.5/10 for this question.**

## Question 5

1. You are designing a new tram line to run on a straight track through an urban area. It will make periodic stops to let people on and off the tram. The average tram speed is 50km/h and the average time spent at each stop is 15 seconds. The average total journey length of a passenger is 10 km.

a) Estimate the average walking speed of an average person.

≈5km/h (anything in the range 3-8 km/h was deemed acceptable).

b) Estimate the average necessary walking distance of a person who rides the tram (including walking both before and after riding the tram) if the stops are spaced 400m apart.

If we assume all travel is along the length of the tram line, then no one should ever walk more than 200m to get to a stop. In the best case scenario, one will be at a stop already and will walk 0m. The distribution of people between these two extremes can be assumed uniform, such that the average distance walked to a single stop is (0m+200m)/2 = 100m. The question asks you to consider both before *and* after riding the tram, so the correct answer is 2 x 100m = 200m.

c) What is the best distance between stops to minimize the average travel time?

Total travel time is the sum of 3 distinct parts: tram driving time, tram stoppage time, and walking time. Let x represent the distance between stops.

$$t_{trip} = t_{drive} + t_{stop} + t_{walk}$$

$$t_{trip} = \frac{10km}{50km/h} + (\frac{10km}{x})(\frac{15s}{3600s/h}) + \frac{x}{2 \times 5}$$

We need to find what value of x minimizes the trip time. This can be done by graphing the above function on a calculator (figure 7) or by simply trying a few values for x and comparing the results (figure 8). Full marks were awarded to students who attempted any kind of minimization procedure.

***Marking Scheme:***

***1 Mark:*** *a) Reasonable walking speed*

***2 Marks:*** *b) About 200m*

***1 Marks:*** *b) An additional point for giving a proper explanation*

***4 Marks:*** *c) Calculating the total trip time for one stop distance, and/or coming up with some form of the* $t_{trip}$ *equation given here.*

***2-3 Marks:*** *c) Finding the best stop distance with a graphing calculator, by testing different stop distances, or by using calculus*

***1 Mark:*** *A logical qualitative argument (e.g. there is a trade-off between walking time and stoppage time)*

***1 Mark:*** *Some logical algebra with no*

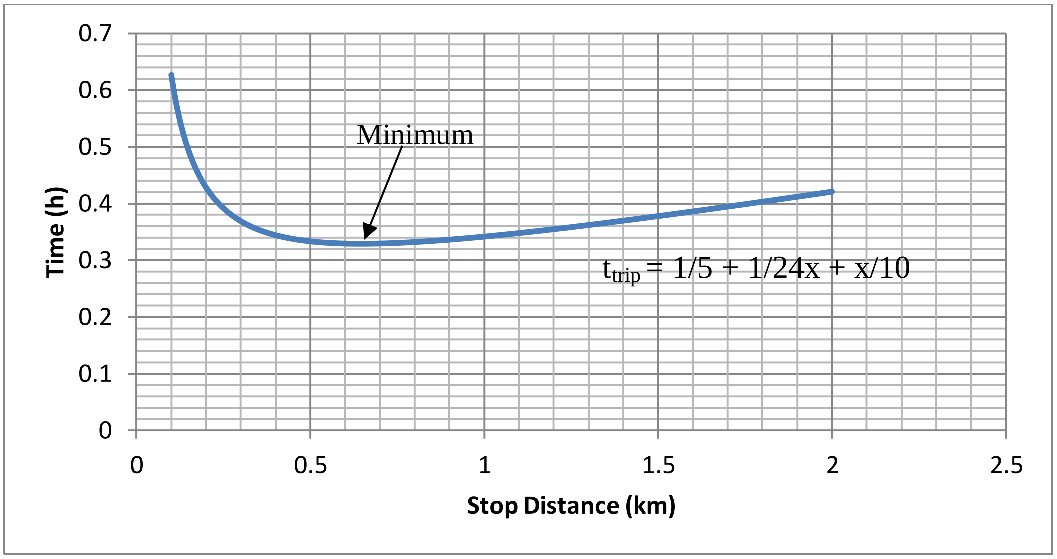


Figure 7: A plot of trip time vs. stop distance shows that the minimum time occurs around 650m.

| x (km) | time (min) |
|---|---|
| 0.300 | 22.133 |
| 0.400 | 20.650 |
| 0.500 | 20.000 |
| 0.600 | 19.767 |
| 0.700 | 19.771 |
| 0.800 | 19.925 |

Figure 8: A table such as this can be used to roughly find the best distance between tram stops.

From the above table, the minimum time appears to be around 600m. The exact minimum occurs at a stop spacing of 645m.

The minimum can also be found using calculus, though that method is outside the scope of the grade 10 science curriculum.

This was the most calculationally intensive question on the contest, and students averaged 1.5/10. Half of the students were able to reasonably estimate an average person's walking speed, and 13% of students correctly answered part b). Part c) proved to be very challenging, with 3% of students attempting some sort of minimization. Marking for part c) was done case by case, so that students with incorrect values from parts a) or b) were not discriminated against in part c) due to propagating errors.

## Question 6

It has been observed in the last few decades in China that the decline in the stork population is correlated with the decline in the human birth rate.

*Due to the open ended-ness of the question, there is no single "right" solution for part a) or b). Instead, we include here some valid answers we got from students.*

a) Can you think of possible reasons for this correlation? Give your answers only in the space below.

- Overpopulation and government policy are influencing family planning. Overpopulation usually causes a lot of pollution too, impacting wildlife.
- Fewer children to look after may mean more working adults, leading to increased urbanization and industrial growth. More commuting and more production will increase pollution, affecting the health of the stork.
- Chinese adults with fewer children will have more money to spend on material items which can take a toll on the environment.
- Since human birth rate is down, less storks are needed to deliver the babies to their families
- If people believe in the stork myth, then with less storks around they might be less willing to try to have a baby
- People are eating storks, and there is something in the stork that negatively affects human fertility
- Storks survive off of litter from children at places like parks
- Storks feed off of pests that spread diseases affecting human fertility

***Marking Scheme:***

***3 Marks:*** *a) A logical idea (not necessarily realistic) that could provide a correlation*

***1-2 Marks:*** *a) An additional, distinct idea*

***2 Marks:*** *b) A justified observation that follows from one of the ideas put forth in part a). E.g. "I will test … in order to find out …"*

***1 Mark:*** *b) An unexplained but relevant thing to observe. E.g. simply*

b) What further observations would you make to test your hypotheses? Give your answers only in the space below.

- Look for similar trends in other developing countries
- Compare stork population vs. human birth rate in rural vs. urban areas
- Compile more data in the coming years to get a larger data set
- Examine industrial growth trends in China
- Examine other bird populations in China to see if they are experiencing similar problems
- Examine the habitat of the stork to determine the impact of pollution on the animal

Students averaged 39% on this question (high compared to other questions), mostly thanks to their creativity in part a). Any hypothesis, absurd or realistic, that would prove correlation *if* it were actually true was given marks. 25% of students' hypotheses involved pollution, and roughly 20% of students mentioned overcrowding/overpopulation. 8% of students suggested that the old stork myth might be a factor too.

## Awards

The highest scoring student received a prize of $500. The 2nd place student was awarded $250, and the 3rd place student $100. The top student from each province who did not receive a national prize was awarded $100. If there had been a tie for the top student in a province, each student in the tie would have received $50. Teachers of all these prize-winning students received a $50 prize. All prizewinners, both students and teachers, received certificates commending their achievements.

Four other types of certificates were awarded, to the top 1%, 3%, 10%, and 25% of students. All students in the top 1% received at least 32/60 marks. The students in the top 3% received at least 28/60 marks. The students in the top 10% received at least 24/60 marks. The top 25% of students received at least 20/60 marks.

## Results Package to Teachers

Teachers were mailed a package containing a list of their students' results, certificates for high-scoring students, and a receipt for payment. For those teachers with a prize-winning student, a cheque for the prize money was also included.

## References

Kashino, Z., et al. (2012). Analysis – Michael Smith Challenge 2012.
http://smithchallenge.ubc.ca/Documents/MSC2012%20-%20English%20Solutions.pdf