Michael Smith Science Challenge

2015

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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 contest is designed to challenge students' logical and creative thinking with a minimum amount of memorization. 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, 134 teachers from 8 provinces registered for the contest, with the provincial registration shown in Figure 1. A total of 1681 students were registered (45% female, 55% male).

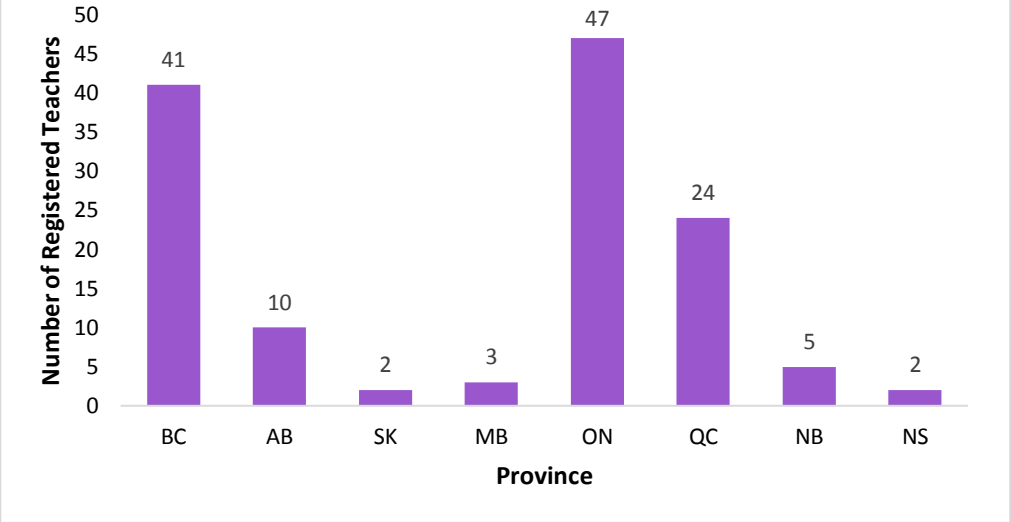


Figure 1: The number of teachers who registered for the challenge in each province.

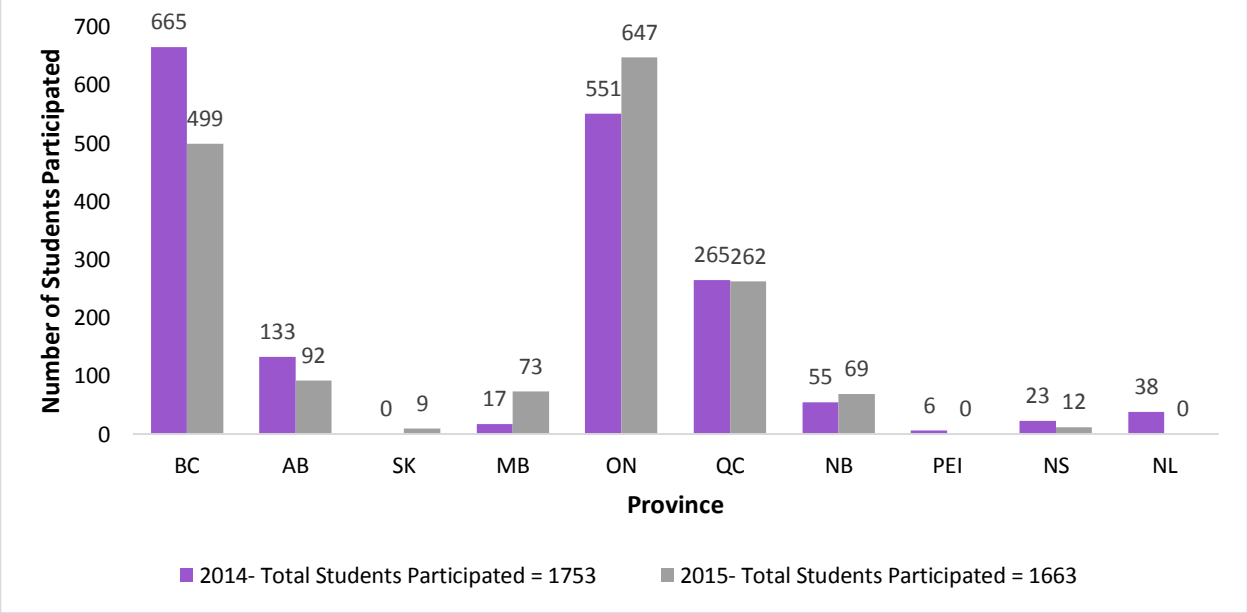


Figure 2: Student participation by province in the 2014 and 2015 Michael Smith Challenges.

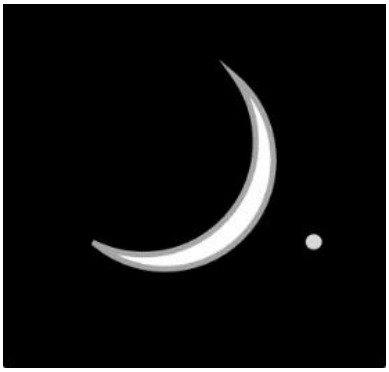
Question 1

Mark Distribution:
***6 marks** (part A)*
***4 marks** (part B)*
***Top mark:** 10/10 (1 student)*

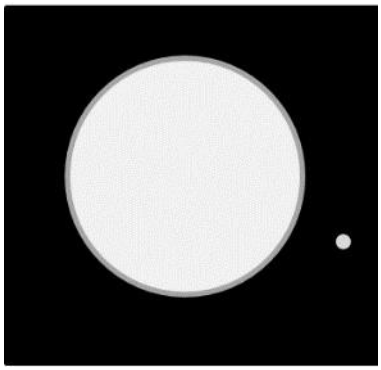
We live in exciting times for solar system astronomy; Curiosity is wandering over Mars, New Horizons is reaching Pluto, and Philae has landed on a comet. Another comet (Lovejoy) is currently visible in the night sky.

a) Consider the pictures below of the Moon and a planet, as viewed from Earth. In each case, which planet could this be? Write all possible answers in the boxes provided.

A. I, II, III, IV or V



B. III, IV or V



Naked-eye planets in order of distance from the Sun:

I. Mercury II. Venus III. Mars IV. Jupiter V. Saturn

Note: shortly before this contest was written, for a couple of nights, Venus (bright white) and Mars (less bright, clearly red) appeared in the evening sky very close to a brilliant crescent Moon.

The intent of this question was to discover if students knew that the inner planets can only be seen very close to the Sun and that the thin crescent Moon indicates the proximity of the newly-set Sun.

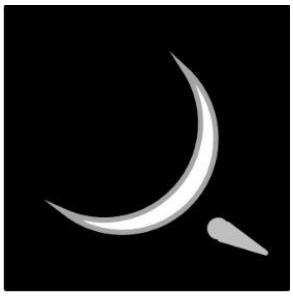
We gave full marks if all planets were shown by the crescent Moon and only Mars and the outer planets were shown by the full Moon. If only the inner planets were shown next to the crescent: 4/6. About a third of students picked the latter option. We also gave 4/6 if the student picked only one planet for each diagram based on a good reason why those planets would be the brightest.

One subtle point not noticed by the author: The planet was depicted by a small circle (for visibility when printed). Some students reasoned that the planet by the crescent Moon could not be Mercury or Venus because they would also appear as crescents (although this needs good binoculars to see). Good! Full marks were given for this reason if everything else was good.

About 10% of students think that Earth's orbit lies between those of Mars and Jupiter. Many students argued with our choice of "naked-eye" planets; some claimed only Mars, Jupiter and Venus are such, others included Uranus, Neptune and Pluto.

b) Consider the pictures below of the Moon and a comet, as viewed from Earth. Circle the letter(s) by the picture(s) that are possible.

A.



B.

C.

D.

E.

F.

Five large and common misconceptions, any of which precipitated a zero on this part of the question:

-"Comet" means "meteorite". Wrong. In this case only the "comets" that appear to be falling down were selected. Many students explicitly said that comets cannot move upwards.

-Celestial bodies move in a two-dimensional shell, and so many of the pictures represented a looming comet-moon collision, or that the comet must be in orbit around the Moon.

-The crescent shape of the Moon is caused by the Earth's shadow. No, that's a lunar eclipse, with the opposite solar position. This erroneous idea is not really relevant to the question but many students volunteered the information anyway.

-The comet and the Moon have the same orbital direction as that indicated by the crescent shape, i.e. down and right in the diagrams. Neither is true. The Moon is going the other way, and comets can go either way around the Sun (e.g. Halley goes the opposite way to the Earth and all the other planets).

-Related to the above: the comet's tail indicates which way it is going. Wrong. The comet's tail is blown away by the solar wind regardless of whether the comet is "coming or going".

One subtle point not noticed by the author: Some diagrams implied that the comet was in front of the Moon; whilst this possible (comets have hit the Earth – e.g. Tunguska 1908, possibly) such a circumstance would cause a major alarm. Marks were awarded for pointing this out.

A few percent of students knew that the comet's tail points away from the Sun, and the Moon's crescent indicates that the Sun must be to the right and below the diagrams. The reason for asking this question is to assess how many students are discovering this easily-accessed information in a year when there has been much cometary excitement.

Question 2

Mark Distribution:
***11 marks** (part A)*
***9 marks** (part B)*
***Top mark:** 20/20 (2 students)*

This year, 2015, is the International Year of Light. Here are some questions regarding the nature of light.

a) The two pictures below were each taken with the same automatic single-exposure digital camera and with the same interior lighting. The pictures were taken from the same position facing a window, one hour apart from each other, in early January. What observations can you make? What explanations can you give? Check all boxes next to correct statements.

7am

8am

	Bright light on one side of the glass stops weak light on the other side of the glass from getting through.
X	It is difficult to see outside from a lit room when it is dark out.
X	The window behaves like a mirror when it is lit predominantly from the observer side.
	The glass is a one-way mirror that only responds when there is less illumination behind the mirror side.
X	The glass reflects a small fraction of the incident light which is only visible if the exterior illumination is low.
	The glass refracts a small fraction of the incident light which creates an image in the glass if the exterior illumination is low.
	Multiple refraction of light in the glass causes an image to form against the dimly illuminated exterior.
	At 8am, the rising sun has warmed the glass, allowing light to pass through.
X	The automatic focus camera focused on the glass in the first picture because it was dark outside.
	The photographer does not have steady hands.
X	There are multiple images in the 7am picture because the window is (assumedly) double glazed.

Point not noticed by the author: the statement “the automatic focus camera focused on the glass in the first picture because it was dark outside” is problematic because there is no way of knowing the focus mechanism of the camera used. Points were neither awarded nor deducted for this choice.

The most common mistake made by students was selecting a choice about refraction of light in the glass. 60% of students who made this mistake chose one or both of the refraction choices along with the choice about reflection. This is most likely due to being unfamiliar with the definitions of reflection and refraction. Since this was the key point in the question, students who selected both reflection and refraction answers could receive a maximum of 7/11. Only about 10% of students chose one of either “at 8am, the rising sun has warmed the glass, allowing light to pass through” or “the photographer does not have steady hands”.

b) The first picture below is taken using visible light and the second (of the same person) is taken using thermal infrared. Infrared radiation is emitted by any body with a non-zero temperature (with more emission from warmer objects). What can you deduce about visible light and infrared light? Check all the boxes next to correct statements.

Visible Light

Thermal Infrared

X	Spectacle lenses absorb infrared light.
	Spectacle lenses transmit infrared light.
	Spectacle lenses absorb visible light.
X	Spectacle lenses transmit visible light.
X	Spectacle lenses emit infrared light.
	Spectacle lenses emit visible light.
	The order of temperature from highest to lowest is: skin, lens, clothing.
X	The order of temperature from highest to lowest is: skin, clothing, lens.
	The order of temperature from highest to lowest is: clothing, skin, lens.

70% of students scored 7/9 - the main mistake was forgetting the inclusion of spectacle lenses emitting infrared light, which could be deduced by reading the introduction to infrared light in the question. 10% of students answered that spectacle lenses emit visible light instead of transmit visible light. Only a few students chose the wrong order of temperature. About 10% of students chose “spectacle lenses emit visible light;” believing that all objects emit visible light is a common misconception.

Question 3

Mark Distribution:
***3 marks** (part A)*
***2 marks** (part B)*
***4 marks** (part C)*
***8 marks** (part D)*
***5 marks** (part E)*
***8 marks** (part F)*
***Top mark:** 30/30 (8 students)*

As the Earth's climate warms, we are increasingly concerned with the effects caused by large amounts of material changing its state: e.g. ice melting, water condensing and evaporating, gas dissolving and coming out of solution, etc.

a) For each of the following situations, how many states of matter are present (not counting the surrounding air)? Circle ONE number.

I) Ice cubes floating in a glass of water

0 1 2 3 4 the ice is a solid and the water is a liquid

II) Aqueous salt solution at room temperature containing 3% salt by weight.

0 1 2 3 4 the salt is dissolved in the water- only liquid is present

III) The contents of an unopened bottle of soda water.

0 1 2 3 4 there are no bubbles in unopened soda- only liquid is present.

This question was designed as a simple prelude to those that follow. It tests students' knowledge of states of matter in common every day circumstances that often lead to misconceptions, such as the salt in salt water having a solid state or gas being present in soda water before the bottle is opened.

Point not noticed by the author: some students may have counted the air above the soda water as being included, as this can be considered part of its contents. Marks were therefore also given for selecting 2, although this does not confirm that the student understood that the carbon dioxide is not in a gaseous state in the soda water. Many students selected the answers 2, 1, 2, which can either be from the inclusion of the air above the soda water, or from the inclusion of the carbon dioxide bubbles not yet present.

One mark was given for each correct answer. 25% of students lost marks as they seemed not to discount to surrounding air (resulting in the answers 3, 2, 2).

b) What is inside the bubbles seen in water that has been continuously boiling for 5 minutes?

Water vapour, steam, water in its gaseous state

This question was designed to analyze students' logical thinking about an everyday circumstance. A common mistake was stating that the bubbles contain oxygen gas, air, or other gases found in our atmosphere. Many students who received full marks also noted that the liquid water had reached its boiling point and had as such changed phase into a gas.

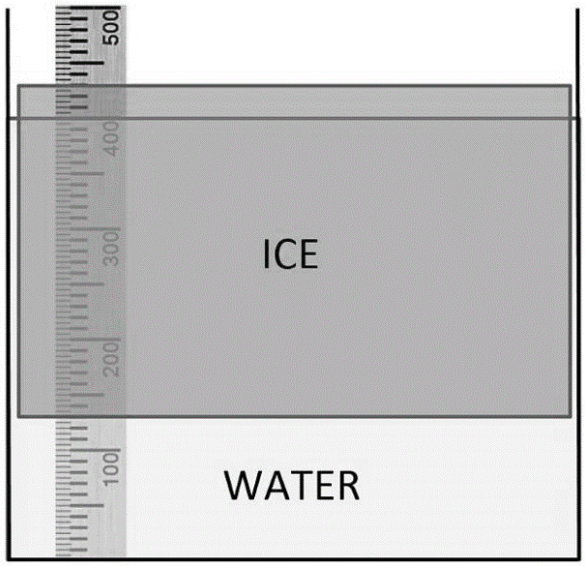
One note on language used in the responses: many students from the same school described the bubbles as "wanting to escape," which did not lose them any marks but is most likely a remark on how their teacher has worded this type of situation.

c) Ice floats on water. Using your knowledge of the structure of liquids, solids and gases, explain briefly why this is called an "anomaly".

Atoms in a liquid are usually further apart than atoms in a solid so a solid should be denser than its liquid form and sink. Solid ice, however, is less dense than liquid water and floats.

Surprisingly, more students received full marks on this part of the question than the previous part, even though this part is more technical. Many students lost marks by generalizing that **all** solids are denser than **all** liquids, which is not true. Some students mentioned hydrogen bonding in the water and depicted the structure of ice to explain why it is less dense, which is not necessary for the question but a good observation as to why this happens. Many students do not seem to understand the concept of density, and instead explained the problem using weight. This unfamiliarity with density is even more apparent in the following questions.

d) The figure below shows pure ice floating in pure water in a glass vessel. The measuring stick is marked in mm. Given that the density of pure water is $1000\ \mathrm{kg/m^3}$, deduce the density of the ice. No prior knowledge of density calculations is needed for this question.



430 mm – 130 mm = 300 mm of ice total

430 mm – 400 mm = 30 mm of ice above the water

400 mm – 130 mm = 270 mm of ice below the water

$$\text{density} = \frac{\text{mass}}{\text{Volume}} \text{ as can be seen by the units}$$

The width and depth of the ice must remain constant due to constraints of the container, and the mass must remain constant as well, so we can relate the height to density

270 mm / 300 mm =mm of ice below water/ total mm of ice = density of ice / density of water = 0.9

0.9 * density of water = 0.9 * 1000 $\mathrm{kg/m^3}$ = 900 $\mathrm{kg/m^3}$

The majority of the students seemed unfamiliar with using units in a problem. Some students quoted a density in mm, which could be a confusion between density and displacement. 10% of students attempted to convert the units of the given density, which is unnecessary and led to many mistakes in units. 40% of students who attempted the question had difficulties reading the ruler which often resulted in the correct steps for the calculation being done with the wrong value. Students were given 4 or 5 marks if the calculation was correct, depending on where the mistake in values was made.

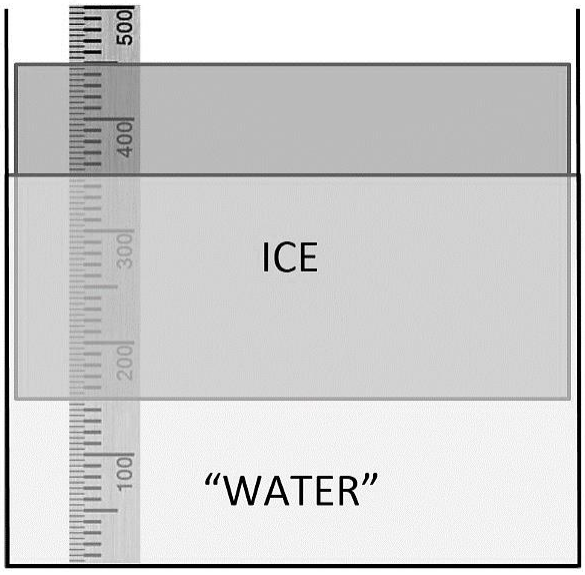
In part c), 75% of students had stated that the density of ice must be less than the density of water in order for it to float, yet in this section 50% of those students stated that the density of ice must be greater than that of water because it is a solid, or derived a density greater than that of liquid water.

e) Assuming the gap between the vessel and the ice is very small, what will the water level be if the ice melts? Why?

The water level will not change. Note the fact that the density goes from 900 kg/m^3 to 1000 kg/m^3 when ice melts. The mass of the ice cannot change, so the volume of the ice must change when it melts in order to match the values. If the density increases, then the volume must decrease by 9/10 its original size (and we can take this to be the height since we know that the width and length of the ice cannot change due to the confinements of the container). This means the water level will not change. 130 mm + (300mm *9/10) = 400 mm

A few percent of students who attempted this problem added their density to the water level to find the new level, but this is incorrect with any values with different units. This displays a misconception with the use of units and how to properly use units in a calculation. The majority of students guessed a value without doing any calculations, or simply stated if the water level would rise, lower, or stay the same.

f) Arctic ice is very pure water but when it melts it does so into salty water. To figure out what will happen to the sea level, consider an exaggerated case below where the ice is pure but the water is very dense. Assuming the gap between the vessel and the ice is very small, what will the water level be if the ice melts? Use the ice density you found in d).



Carry over the density of ice = 900 kg/m^3

From this image, we can see that the ice is floating with 2/3 of its volume submerged under the “water”. When the ice melts, it goes from 900 kg/$m^3$to 1000 kg/m^3 (before mixing with the “water”). Same as before, we can see that the ice will reduce by 1/10 its original height in order to balance the density equation (since mass is conserved and the width and length of the ice are unable to change due to the confinements of the container.) This means that the new water level is 150 + (300 *9/10) = 420 mm, an increase of 70 mm

The context in the question introduction will tell you that we should expect the water level to rise, as that is the current concern with pure Arctic ice melting into the ocean. 60% of students overlooked this fact, however, and stated that the water level should go down.

Question 4

Mark Distribution:
4 marks *(part A)*
6 marks *(part B)*
10 marks *(part C: 4 marks per cause and 2 marks for the data analysis)*
Top Mark: *20/20 (2 students)*

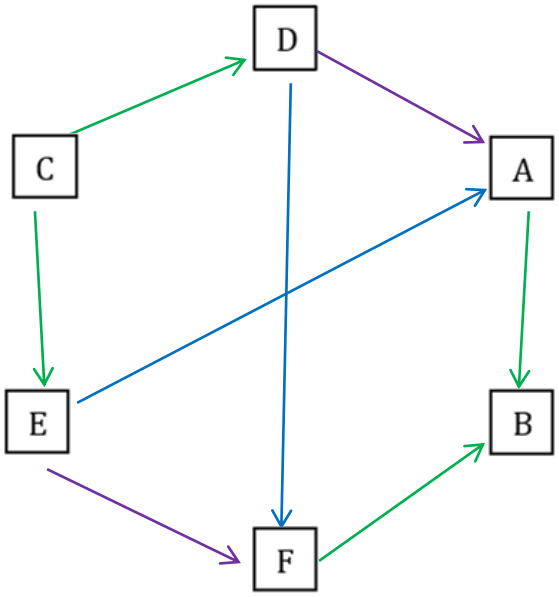
In order to monitor the health of the biosphere and how it is coping with human impacts, it is important to understand how all the elements of the natural world interact with each other. Consider the following example. In 2000, a group of biologists determined the biomass of each species present in an ecosystem. This table displays their results:

Species	Biomass (kg)
A	1200
B	300
C	200,000
D	10,000
E	15,000
F	800

a) Construct a food web using the skeleton provided by drawing arrows between the species to indicate the flow of energy through the ecosystem. Assume each species will only eat another species on a trophic level one below theirs.

Any answer including either one set of the purple or blue arrows or both sets received full marks. The idea is that the energy transfer through an ecosystem is inefficient, and that energy and biomass decrease by approximately a factor of 10 as you move up the trophic levels.

The most common pitfalls of students were: -assuming biomass correlated to the weight of the species. This demonstrates a lack of understanding of what "biomass" means in an ecosystem



-70% of students drew a linear food web. This demonstrates a lack of understanding of energy transfer. Students were awarded part marks if the food web went in order of descending biomass

- disregarding the note that each species will only eat another on one trophic level below their own. This resulted in a huge block of arrows in the middle and was precisely the reason for adding this note. Students who did this were awarded part marks if the trophic levels for each organism were correct

-drawing the arrows facing in the wrong direction. The arrows are meant to signify energy transfer from one organism to another; many students drew their arrows to signify that organism consuming the other.

b) The species recorded in the ecosystem were: mice, foxes, lizards, butterflies, cougars, and apple trees. What could each species in the table above possibly have been?

A: lizards OR foxes

B: cougars

C: apple trees

D: mice OR butterflies

E: butterflies OR mice

F: foxes OR lizards

A common mistake was switching mice and lizards; about 40% of students did this. Another common pitfall was ordering the animals to correlate their weight to biomass; 20% of students has this type of answer.

c) Data were collected again in the same area in 2010.

Species	Biomass (kg)
A	1200
B	200
C	250,000
D	11,000
E	8000
F	600

What could have caused the change in species E? Give one natural and one human disturbance.

Natural Cause: Some possible answers for a natural disturbance include:

-Migration of species E away from the ecosystem (for a number of reasons; e.g. the first set of data was taken during the summer and the second set was taken during the winter and species E migrates for the winter months)

-Immigration of species D into the ecosystem means more competition for the food source. If species D is stronger/ can obtain the food more easily than species E, less food becomes available for species E and the carrying capacity of species E decreases

- Disease in species E has been killing off a part of the population

Human Cause: Some possible answers for a human disturbance include:

-Hunting, capturing, pest control of species E

-Habitat loss from development/ logging (not of apple trees)/ other human activity has left species E more vulnerable to predation since they are a primary consumer; a reason as to why apples trees have increased must also be included for full marks

-Pollutants in the water/ food/ air could be negatively affecting species E's health, which is more sensitive to pollutants or toxins than the other organisms in the ecosystem

What did you notice about the differences between the 2000 and 2010 data?

A stayed the same, B, E and F decreased in biomass, C and D increased in biomass

90% of students lost marks because they did not ensure that their reasoning agreed with the data values given above. The purpose behind asking students to compare the data tables was to get them to recognize the changes in all of the species and propose a cause accordingly. Students were given part marks as long as their reason was plausible despite the numbers, but full marks were only awarded for marks that made sense for the entire ecosystem. About 30% of students wrote “deforestation” for their human cause; this answer received partial credit for two reasons: the number of apple trees went up so deforestation does not make sense with the number of producers present, and students did not elaborate on *how* this will affect species E in particular in a way that coincides with the other biomass values. A large number of students did not explain their answers thoroughly enough to explain the population decrease in species E, or did not specify as to why their reason could only harm species E and not the other organisms in the ecosystem. Some students did not take into account the time frame and had answers (such as adaptation) that would only occur over a longer period of time. Many students also used the scientific term adaptation incorrectly.

Results

Overall

The mark distribution is shown in Fig. 4. The mean was 34.2% and the standard deviation was 10.3%. The mean scores for each question are shown in Fig. 5.

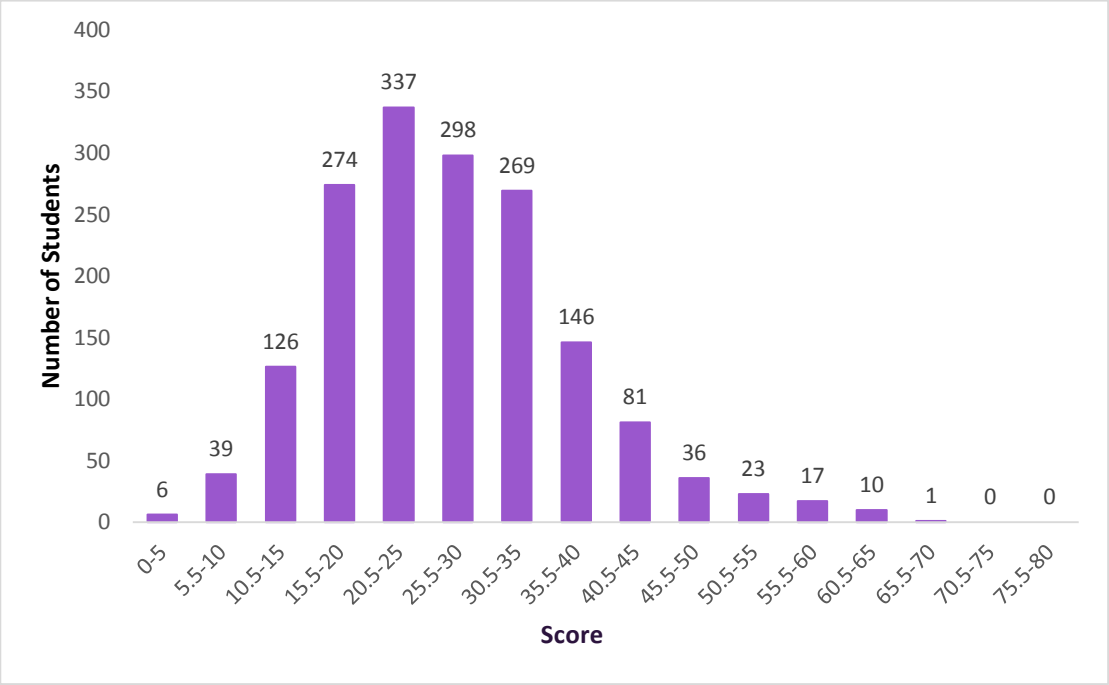


Figure 4: Chart showing the distribution range of marks. The highest mark achieved was 82.5% and the average was 34.2%.

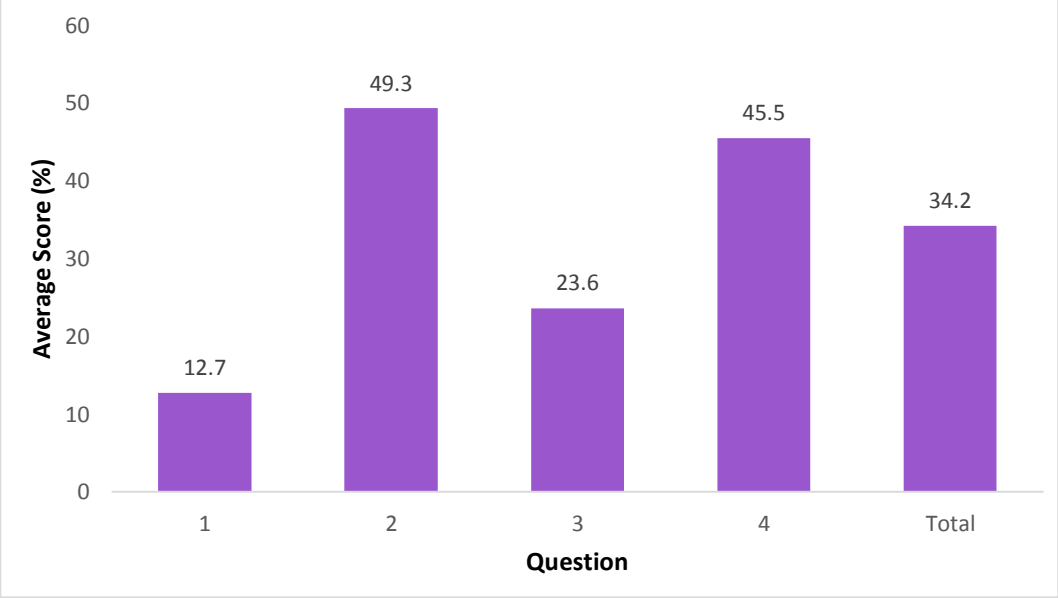


Figure 5: Chart showing the average score on each question.

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. Teachers of all these prize-winning students received a $50 prize. All prizewinners, both students and teachers, received certificates.

Three other types of certificates were awarded, to the top 1%, 3%, and 10% of students. All students in the top 1% received at least 59/80 marks. The students in the top 3% received at least 51/80 marks. The students in the top 10% received at least 41/80 marks.

References

Gadsby, O., et al. (2014). Analysis- Michael Smith Challenge 2014.