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# THE SCIENCE EDUCATION REVIEW

Ideas for enhancing primary and high school science education

## Did you Know?

### *Personality and Brain Structure*

Personality traits can be divided into five factors: conscientiousness, extraversion, neuroticism, agreeableness, and openness/intellect. With the exception of openness/intellect, scientists have found that the size of different parts of people's brains correspond with their personalities. For example, extroverted people tend to have a significantly larger orbitofrontal cortex, while a larger lateral prefrontal cortex is found in conscientious people.

*Source*: Brain structure and personality. (2010). *Journal of College Science Teaching, 40*(1), 12-13.

## Teaching Ideas

Techniques, demonstrations, activities, alternative conceptions, critical incidents, stories, and other ideas

### *Roll Over, Rover*

This is a humorous way to demonstrate the effect of induced charge. Inflate and tie a long, cylindrical balloon of the type used by clowns to make animal shapes and use a marker pen to write the word *Rover* along one side of the balloon. Allow the ink to dry. Place the balloon horizontally against a board or wall, release it, and watch it fall.

Charge the balloon negatively by rubbing its entire length with hair or rabbit fur, place it against the board again with the word Rover facing students, say "stay, Rover," remove your hands, and observe the balloon remain in place on the board as a result of attraction between the charge on it and the induced charge on the board. Similarly charge the other balloon, place it above the marked balloon, lower it slowly while saying "roll over, Rover," and observe the repulsive force between the like-charged balloons cause the marked balloon to roll once. Recharge the unmarked balloon and make "Rover" roll again. Repeat this process, causing Rover to progressively roll down the board.

*Source*: Shaw, M. (2011). Roll over, Rover. *The Physics Teacher, 49*, 248.

## *Dancing Dots and the Characteristics of Living Things*

The following are seven, generally-agreed characteristics of living things: 1. homeostasis, 2. complex cellular organization, 3. ability to reproduce, 4. metabolism, 5. growth and development, 6. ability to adapt and evolve, and 7. ability to respond to stimuli. Note that, contrary to typical student opinion, movement is not regarded a characteristic of a living thing.

The "mercury monster" activity has been commonly used to generate discussion about the generally accepted characteristics of living things. When a solution of dilute nitric acid and potassium dichromate is mixed with liquid mercury sitting in a watch glass, the mercury moves in a manner similar to an Amoeba. However, safety considerations now render this activity unsuitable.

As an alternative, try the Dancing Dots activity, as follows:

- Soak five paper punch-out dots well in 50% isopropyl (rubbing) alcohol solution in water.
- Use tweezers to remove a dot from the alcohol solution and gently place it, flat side down, on the surface of the water in another vessel. If you drop the dot on the surface it will likely sink.
- Observe the motion of the dot over the surface of the water for a few seconds. Repeat using each of the other dots.

The dots move as a result of irregularities in the surface tension caused by the mixing of the alcohol and water. A short YouTube movie of motile Euglena or Paramecium can be used to display similar motion. When disposing of the solution containing the dots, a strainer may be used to catch the dots.

*Source*: Mickle, J. E., & Aune, P. M. (2011). A simple, inexpensive, dynamic, & hands-on exercise for prompting discussion of the characteristics of living things. *The American Biology Teacher*, *73*(3), 164-166.

## *Survey Your Students*

Burgmayer (2011) recommends surveying students about 6 weeks into a school year in order to monitor classroom environment, foster classroom community, and broaden the perspectives of both students and teacher. Items such as the following might be shown to students on a Friday and administered as a survey the following Monday, thus allowing students a weekend to think about their responses:

1. Describe your overall impression of this class.
2. Which activities do you find helpful for learning?
3. Which activities do not help learning?
4. Please list activities you would like to do.
5. Describe how the teaching in this class helps you learn.
6. Describe how the teaching in this class hinders your learning.
7. What advice would you like to give your teacher about his or her teaching?
8. Do you have any other suggestions about learning and/or teaching in this class?

The survey may take either a paper or online format, with the latter ensuring anonymity. While the class should be identified on each survey form, leaving students names optional may promote more honest responses. Free, online surveys may be conducted using Google Forms (an option within Google Docs) or Survey Monkey (http://www.surveymonkey.com).

Analyze the survey responses in one sitting, grouping responses and presenting the results in graphical form (e.g., bar graphs that show the frequency of various student comments). Devote one lesson to discussing the results, inviting students to act like scientists in scrutinizing the data. Perhaps more information is desirable via a follow-up survey. Ask students what changes the results are suggesting. At the same time, respond to student suggestions but without being domineering. During a later class, spend 10 minutes describing what, if any, changes will be made to classroom practices and why these changes are being made.

*Reference*

Burgmayer, P. (2011). Ask the experts [Idea Bank]. *The Science Teacher, 78*(1), 64-65.

## *Pooling Data Using Google Forms*

It is sometimes useful to combine the experimental results or calculations of all groups or individuals in a class. For example, collecting object and image distances associated with a curved mirror can be time-consuming, so pooling three to five measurements from each group can generate a larger set of data very quickly. The free Google Forms facility provided within Google Docs is usually used to collect survey responses. However, by changing the question numbers to other headings such as object distance, image distance, and group number, data can be readily collected from students having Internet access through computers or other web-enabled devices.

Create, name, and save a new form within Google Docs and provide students with access to the form using the web address provided at the bottom of the form. When a set of data is entered into the form it automatically appears as a new line in a spreadsheet with the same name stored in Google Docs on the teacher's computer. The group identification included in the data allows the teacher to identify any problematic data, consult with the relevant group, and delete from the spreadsheet any data that is not appropriate.

With the class data collected in spreadsheet form, it can readily be manipulated and/or plotted by the teacher (or perhaps even by students) using the provisios with a Google spreadsheet to use formulae and charts. For more advanced curve-fitting processes, the data can be copied into Excel. To reuse a spreadsheet, simply select and delete the rows of data.

*Source*: Bonham, S. (2011). Whole class laboratories with Google Docs. *The Physics Teacher*, *49*(1), 22-23.

## *Google Docs for Collaborative Lab Reports*

Science is a collaborative activity, with it now being rare for an individual to be working alone on the next major scientific breakthrough. In school and undergraduate laboratories, it is good pedagogy to also have students collaborating by working in small groups (i.e., pairs or groups of 3). While a lab may be completed by a group, it is common for students to be asked to submit individual reports, but there may be value in providing for them to also experience the preparation of a collaborative lab report.

Google Docs is a free word processor with the basic features of other commercial software that include fonts, text formatting, document layout, tables, equation editor, drawing, and insertion of images. Students may become familiar with Google Docs by being asked to use it to prepare and submit at least one individual lab report. However, Google Docs is particularly useful for collaborative reporting, where each member of a group is typically responsible for individually preparing specific sections of the report, because it provides a revision history that allows the teacher to check on, and even grade, the contribution to the report made by each member of a group and also provides for the document to be shared with other members of the group and the teacher. There are two permission levels for sharing, read only and edit, and the first may be used by a group leader to submit a report to the teacher online.

*Source*: Wood, M. (2011). Collaborative lab reports with Google Docs. *The Physics Teacher, 49*(3), 158-159.

## *Can a Single Fixed Pulley Provide Mechanical Advantage?*

*By*: Vladimir D. Yegorenkov, V.N.Karazin Kharkov National University, Kharkov, Ukraine
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I start with a typical statement present in almost any school textbook in physics:

> A pulley that is attached to something that holds it steady is called a fixed pulley. The fixed pulley makes work easier by changing the direction of the force. A fixed pulley allows you to take advantage of the downward pull of your weight to move a load upward. It does not, however, reduce the force you need to lift it.

The conventional textbook description illustrated in Figure 1 contains no mention of the location of the person pulling the rope, although the diagrams in some books show that the person pulling the rope is standing on the floor, which is the case usually discussed in schools. Meanwhile, window cleaning platforms for skyscrapers, for example, which are to be frequently seen in large cities nowadays, operate fundamentally by persons on board lifting themselves to a desired location on the walls. So, along with the conventional arrangement with the pulley, I usually discuss with students another one where a person is lifting himself or herself in a way similar to the operation of window cleaning platforms.

*Figure 1*. The conventional textbook depiction of a fixed pulley in action.

I have gained additional experience in the context of my family. When my two sons were young, I installed some training devices in the children’s room to help their physical development. Among them was a home-made pulley device similar to that shown in Figure 2. The pulley had a groove around its circumference and was fixed to the ceiling. An endless rope was run over the pulley, forming one loop hanging almost to the floor. A seat was fixed to the rope and a child could sit on the seat and use the rope to pull himself or herself almost to the ceiling. Of course, the full length of rope had to be pulled through the child’s hands to get there. To save a child who had let go of the rope from falling and hitting the floor, a knot in the rope that would not pass around the pulley was positioned appropriately in the rope.

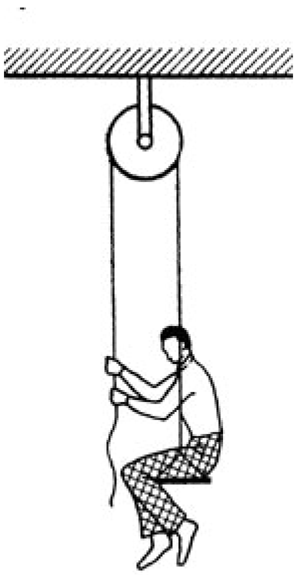

*Figure 2*. The home-made, fixed-pulley training device

Let the person in Figure 2 pull on the rope with a force of magnitude *T*. The tension in the rope will also be *T*. At equilibrium, this force is balanced by a force equal to $mg - T$ on the person's side of the pulley. Therefore, $T = mg - T$, from which we see that the mechanical advantage (load/effort, which is $mg/T$ in this case) of the device is 2.

My children had plenty of experience with this device. However, when my younger son began to attend school he heard from a physics teacher that a fixed pulley does not provide mechanical advantage. He asked the teacher why it was easy for him to get to the ceiling using his fixed pulley and rope at home whereas he could not lift himself on a cross-bar in a gym. The teacher could not answer and asked my son to invite me to the class to help clarify the situation.

When I visited the class, I found it impossible to reproduce the home arrangement. However, to still use the occasion to demonstrate the mechanical advantage, I asked two boys to bring a 7-L pail of water, fixed one end of a piece of rope to a hook on the wall, passed the other end of the rope through a pulley, and hung the pail on the rope to provide a set-up similar to that shown in Figure 3. I then asked the smallest girl in the class to lift the pail off the floor by pulling on the free end of the rope, a task that she performed easily with one hand. Of course, here the pulley was movable, but the mechanical advantage is still 2, as for the fixed pulley situation of Figure 2. Many people visited our flat, with the home-made device invariably impressing them all, both young and old. They did not expect that it would be so easy to move themselves up the rope.

*Figure 3*. The movable-pulley arrangement used for the classroom demonstration.

A more complicated construction can make the mechanical advantage of self-raising equal more than 2. For example, the mechanical advantage of the device shown in Figure 4, comprising a fixed and movable pulley and four lengths of rope designated *a-d*, is 4.

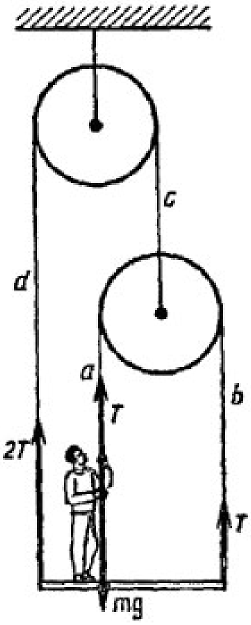


*Figure 4*. A more complicated device that allows a person to self-lift with a mechanical advantage of 4.

The main point, then, is that textbook pictures are often schematic to the extent of being incomplete from the point of view of the mechanical forces involved and are therefore potentially misleading. For example, neither Figures 1 nor 3 provide information about the position of the person holding the rope and a reader cannot construct a true balance of forces. So, returning to the question that comprised the heading of this piece, namely “can a single fixed pulley provide mechanical advantage?” we see that the answer is “yes,” as exemplified in Figure 2.

***Acknowledgement***

The author would like to express his gratitude to Peter Eastwell for helpful cooperation and suggestions during the preparation of this manuscript.

# Science Poetry

Reading and/or listening to poems composed by other children their own age can inspire and reassure students as to their ability to understand and write poetry, and the science poems in this regular section of *SER* may be used for this purpose. Please find information about the *International Science Poetry Competition* at http://www.ScienceEducationReview.com/poetcomp.html .

## I Want to be an Astronaut

I want to be an astronaut
And fly up to the stars
To visit all the planets
And see the moons of Mars.

Mercury close to the sun
And Venus nice and hot
Earth is where we like to live
It is the perfect spot.

## Redox

Grade 11 Chemistry –
A subject I hold dear
Has launched me on a voyage
Of discovery this year.

I've garnered an acquaintance
With the periodic table
I've met my share of elements
Some volatile - some stable.

Mars, oh so red and rusty
Its deserts hot and dry
Jupiter with many moons
The biggest planet in the sky.

Saturn with its rings of rock
The prettiest planet of all
Uranus cold and bluey-green
A giant icy ball!

Stormy Neptune so far away
It's filled with methane gas
And little Pluto, planet or not
It has the smallest mass.

All these planets are very nice
It would be great to stay
But Earth has everything I need
I'll visit space another day.

*Isabelle Spencer, 10 years*
*Australia*

Balancing equations
And acid-base reactions
Have joined my growing repertoire
Of chemical transactions.

With confidence an all-time high
And keen anticipation
I've moved on to the study of
A thing called oxidation.

Iron oxidises
To form a red-brown dust
That's known as ferric oxide
Or commonly, as rust.

Verdigris on copper
Is another oxidation
A lacy tracery of green
That's viewed with admiration.

What makes an apple slice turn brown?
What causes fruit to rot?
You've guessed it - oxidation's
At the centre of the plot.

Oh no, I've had a scary thought!
My grandpa looks quite wrinkled
And brownish blotchy splotches
All o'er his skin are sprinkled.

I thought it just a sign of age
But now I'm realizing
My grandpa's not just getting old
I think he's oxidising!

*Jack Burnham, 16 years*
*Australia*

# Ideas in Brief

Ideas from key articles in reviewed publications

## *The Sixth Great Mass Extinction: A New Curriculum Theme for Science Educators*

*By*: Ron Wagler, The University of Texas at El Paso, El Paso, TX, USA rrwagler2@utep.edu

There have been five great mass extinctions during Earth's history (Erwin, 2001; Jablonski, 1995). All of these extinctions were characterized by "a profound loss of biodiversity during a relatively short period" (Wake & Vredenburg, 2008, p. 11466). There is a ever-increasing scientific consensus that humanity has entered a sixth great mass extinction (e.g., Alroy, 2008; Jackson, 2008; Lewis, 2006; McDaniel & Borton, 2002; Rockström et al., 2009; Rohr, Raffel, Romansic, McCallum, & Hudson, 2008; Steffen, Crutzen & McNeill, 2007; Thomas et al., 2004; Wake & Vredenburg, 2008; Zalasiewicz, Williams, Steffen, & Crutzen, 2010).

Unlike the last five great mass extinctions, "human activities are associated directly or indirectly with nearly every aspect of the current extinction spasm" (Wake & Vredenburg, 2008, p. 11472). These human activities have taken many forms, with the most devastating and far-reaching anthropogenic direct drivers affecting global biodiversity being the spread of invasive species and genes, overexploitation of species, habitat modification, fragmentation and destruction, pollution, and climate change (Millennium Ecosystem Assessment [MEA], 2005; World Wide Fund for Nature [WWF], 2010).

Global biodiversity species numbers have been greatly impacted by these human activities. Humanity has accelerated, over the past 200 to 300 years, global species extinction rates 100-1,000 times Earth's historical geological background rate (Pimm, Russell, Gittleman, & Brooks, 1995; Rockström et al., 2009). Modeled future extinction rates are projected to be 10,000 times Earth's historical geological background rate (MEA, 2005).

One component of possibly reducing the increasing anthropogenic affects associated with the current sixth great mass extinction is education. The sixth great mass extinction constitutes a newly-emerging scientific theme that has great potential in science education. The sixth great mass extinction also provides an inquiry-based, relevant, and integrative theme for educating students about global environmental degradation and global environmental degradation reduction.

Because of these characteristics, the current sixth great mass extinction offers an abundance of educational opportunities for science educators. The five major global anthropogenic direct drivers of biodiversity loss associated with the sixth great mass extinction provide an excellent framework for presenting the complexity and human challenges of this mass extinction. The following lists these direct drivers. Under each direct driver, broad science curriculum topics are presented that can be utilized by science educators.

*Major anthropogenic direct driver of biodiversity loss: Habitat modification, fragmentation, & destruction*. Relevant science curriculum topics include:

- Acid rain's impact on habitat loss
- Effects of global warming on habitat (e.g., polar ice cap reduction and sea level rising)
- Deforestation rates and locations

- Effects on invertebrate biodiversity (e.g., corals, insects, crustaceans, and arachnids) because of habitat modification, fragmentation, and destruction
- Examples of habitat modification, fragmentation, and destruction (e.g., Madagascar and North American tallgrass prairie)
- Impact on a species' evolution (e.g., reduced gene flow and genetic drift) because of habitat modification, fragmentation, and destruction
- Impact on endangered and threatened species because of habitat modification, fragmentation, and destruction
- Association between human population dynamics (e.g., population growth, population density, factors that affect and regulate population growth) and habitat modification, fragmentation, and destruction
- Impact on global carrying capacity because of habitat modification, fragmentation, and destruction
- Impact on trophic levels, food chains, food webs, and energy flow within ecosystems because of habitat modification, fragmentation, and destruction
- Past and current species extinctions associated with habitat modification, fragmentation, and destruction
- Physical alteration of waterways and its impact on habitat
- Role of habitat modification, fragmentation, and destruction in species extinction
- Impact of habitat modification, fragmentation, and destruction on erosion and sedimentation rates
- Impact of habitat modification, fragmentation, and destruction on natural cycles (e.g., rock)

*Major anthropogenic direct driver of biodiversity loss: Overexploitation of species*. Relevant science curriculum topics include:

- Examples of overexploitation of species (e.g., American bison and Galapagos tortoise)
- Impact on a species evolution because of overexploitation (e.g., reduced fitness and reduced gene pool variability)
- Impact of overexploitation of species on endemic, endangered, and threatened species
- How the goal of environmental sustainability is affected by overexploitation of species
- Effects of overexploitation of species on vertebrate biodiversity (e.g., fish, amphibians, reptiles, bird, and mammals)
- Association between human population dynamics (e.g., population growth, population density, factors that affect and regulate population growth) and overexploitation of species
- Examples of species extinctions because of overexploitation
- Overexploitation of species and its impact on predator-prey cycles
- Overexploitation of species and its impact on trophic levels, food chains, food webs, and energy flow within ecosystems
- Overexploitation of species role in species extinction
- Overexploitation of tropical humid forests and other forests
- Past and present species extinctions associated with overexploitation of species

*Major anthropogenic direct driver of biodiversity loss: The spread of invasive species & genes*. Relevant science curriculum topics include:

- Effect of global warming (e.g., increased range of invasive species)
- Examples of invasive species (e.g., Guam [brown tree snake] and Australia [cane toad])

- Impact of invasive species on endemic, endangered, and threatened species
- Impact of invasive species on noninvasive species' evolution (e.g., natural selection) and coevolution
- Impact of invasive species on predator-prey cycles
- Impact of invasive species on trophic levels, food chains, food webs, and energy flow within ecosystems
- How the goal of environmental sustainability is affected by the spread of invasive species and genes
- Invasive species' role in species extinction
- Influence of invasive species and genes on biodiversity, biocapacity, species richness, genetic diversity, and ecosystem diversity

*Major anthropogenic direct driver of biodiversity loss: Pollution*. Relevant science curriculum topics include:

- Acid rain
- Air pollutants (e.g., carbon monoxide, nitrogen dioxide, sulfur dioxide, lead, $PM_{2.5}$, and $PM_{10}$)
- Pollution's impact on natural cycles (e.g., carbon, nitrogen, sulfur, and phosphorus)
- Bioaccumulation and biomagnification of chemicals (e.g., mercury and PCBs) in food chains
- Chlorofluorocarbon (CFC) and stratospheric ozone depletion (i.e., the ozone hole)
- Eutrophication and anoxia
- Association between per capita human ecological/carbon footprint and pollution
- Association between human population dynamics (e.g., population growth, population density, factors that affect and regulate population growth) and pollution
- Soil pollutants (e.g., hydrocarbons, heavy metals, herbicides, and pesticides)
- Bioindicators (e.g., amphibians) as a way to determine pollution's impact on ecosystems
- Mercury deposition
- Pollution's impact on a species' evolution (e.g., mutation)
- Pollution's impact on human health
- Pollution's impact on predator-prey cycles
- Pollution's impact on trophic levels, food chains, food webs, and energy flow within ecosystems
- U.S. superfund sites
- Water pollutants (e.g., volatile organic compounds and fertilizers)

*Major anthropogenic direct driver of biodiversity loss: Climate change*. Relevant science curriculum topics include:

- Effect of global warming (e.g., change in precipitation patterns and problems for agriculture)
- Climate change's impact on predator-prey cycles
- Association between per capita human ecological/carbon footprint and climate change
- Deforestation's role in climate change
- Consequences of climate change on producers, consumers, and decomposers
- Role of greenhouse gases (e.g., carbon dioxide, methane, surface ozone, and nitrous oxide) in climate change

- Relationship between atmospheric carbon dioxide and ocean acidification
- Ocean acidification’s impact on organisms
- Effects of climate change on plant biodiversity
- Impact of climate change on trophic levels, food chains, food webs, and energy flow within ecosystems
- Increased desertification as a result of climate change
- Alteration of natural cycles (e.g., water) because of climate change
- Role of climate change in species’ extinction

Clearly, the greatest challenge facing humanity is stopping the destruction of the very biosphere that sustains us. Ultimately, educating students about the sixth great mass extinction is an essential component in providing students with the knowledge and skills necessary to be scientifically literate citizens (American Association for the Advancement of Science [AAAS], 1993; Rutherford & Ahlgren, 1990) that can fully participate in this, humanities greatest challenge. For further information about the sixth great mass extinction, please see Wagler (2011a, 2011b). Both articles provide detailed scientific information associated with the sixth great mass extinction and further sixth great mass extinction educational resources that can also be utilized in the classroom.

*Acknowledgement*

The list of five major global anthropogenic direct drivers of biodiversity loss associated with the sixth great mass extinction, together with relevant, broad science curriculum topics for each, is a reproduction, with permission, and modification from Wagler (2011a).

*Resources and References*

An * designates that the resource is freely available online and can be incorporated into middle school, high school, and college science curricula.

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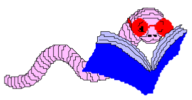

# Research in Brief

Research findings from key articles in reviewed publications

## *Is Adolescents' Declining Motivation to Learn Science Inevitable?*

*By*: Dana Vedder-Weiss and David Fortus, Weizmann Institute of Science, Rehovot, Israel
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Many educators agree that an important goal of science education should be to develop the foundation for lifelong learning, including the motivation to learn science in school, out of school, and after school. Many studies have shown that students' attitudes, interest, and motivation towards science learning decline throughout their years at school, especially during secondary school, and reviews of such studies may be found in Galton (2009) and Osborne, Simon, and Collins (2003). Vedder-Weiss and Fortus (2011) presents results suggesting that students' declining motivation to learn science between fifth and eighth grade is not inevitable. They found that students' motivation to learn science develops differently at different school types. In traditional Israeli schools, students' motivation declined from fifth to eighth grade. This decline was apparent in students' motivation for school science learning (personal mastery goals and classroom engagement) as well as in their continuing motivation (engagement in and rejection of extra-curricular science-related activities). However, in democratic schools, the levels of personal mastery goals, classroom engagement, and continuing motivation stayed more or less stable throughout these years. The results suggest that the non-declining motivation of adolescents in democratic schools is not a result of home influence but rather is related to their schools' culture.

Prominent features of the democratic schools' culture are: (1) school is managed by shared decision-making among the students and staff, (2) students can choose which subjects to learn and, in general, what to do with their time, and there are usually no required classes, (3) the staff supports students by offering facilitation according to students' interests and needs, (4) teachers have great autonomy in designing their teaching, (5) qualitative evaluation methods are usually used, (6) classes are often multi-aged, and (7) the number of students in each class is relatively small. Further research should focus on investigating which features of school culture or teachers' instructional practices are responsible for the different trends in students' motivation to learn science.

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# Readers' Forum

## *Air Curving Around an Object*

"Try This" (2011) describes the interesting activity of placing a lit candle behind a curved glass, blowing air onto the front surface of the glass, and observing the blown air extinguish the candle flame even though the candle is "hidden" behind the glass. However, I find the explanation for why the air steam bends around the curved glass surface to be erroneous and confused. For example:

- It is not true to say that "since the air blowing from your mouth is moving faster than the air surrounding it, it's lower in pressure" (p. 59). This is the classic misrepresentation of Bernoulli's principle. Air does not have a reduced static pressure simply because it is made to move. Indeed, the lateral (or static) pressure of the air blown from one's mouth is the same as that of the surrounding air (i.e., 1 atmosphere pressure).
- While air can push on an object, it does not pull on an object.
- The air stream bends around the glass because it is pushed sideways rather than being pulled.

For a treatment of entrainment, the Coanda effect, and Bernoulli's principle, including the bending of a stream of air around a curved object, please see Eastwell (2007), which is freely available online.

*References*

Eastwell, P. H. (2007). Bernoulli? Perhaps, but what about viscosity? *The Science Education Review*, *6*, 1-13. Available from http://www.scienceeducationreview.com/open_access/index.html .
Try this: Blowing around corners. (2011). *Teaching Science, 57*(2), 58-59.

*Peter Eastwell, Science Time Education, Queensland, Australia*

## ? ? ? ? ? Your Questions Answered ? ? ? ? ?

This section of *SER* responds to readers' queries, so please submit your question to The Editor at editor@ScienceEducationReview.com . Have that long-standing query resolved; hopefully!

### *"Travelling" Teacher*

***I teach Biology to five high school classes, each having about 27 students, using four different classrooms, none of which are "my own." Can you please suggest good ways to do laboratory experiments with the students? I don't feel that being a "travelling" biology teacher is conducive to student achievement, and feel as if I am slighting my students. All students do have ibooks, providing them with access to the internet. Help me!***

You're not the one slighting your students; the system is. Traveling science teachers are limited because they do not "own" the classrooms and cannot set up permanent displays/experiments. Is there any way the "keepers" of those four classrooms could give you at least a portion of permanent space in there? Of course, you wouldn't be there to watch over any projects, so that is not an ideal solution either, but it might work.

I would obtain a good-sized roll-about cart (or two) and transport project/experiment supplies that way. I would also assign many simple experiments as homework, providing students with detailed instructions and forewarning parents as to what supplies will be needed. You didn't state what grade level/s you are teaching and of course experiments for lower grades are generally much simpler than ones for middle or high school.

I would also become quite vocal regarding the situation to parents, PTO, and the school board. If they are not aware of the problem, they can't take steps to correct it. I would tell them that the goal of science instruction today is to provide hands-on involvement for as many students as possible, and that with the current arrangement you are greatly limited by the kinds of experiments you can do and can only demonstrate rather than have students actively participating in experiments. Good luck; my heart goes out to you.

*Terry Keck*

My first few years of teaching biology required traveling. The rooms were on different floors of the same building. I found that using a two-shelf cart was the best way to move the lab materials from room to room. Use small baskets for each of your lab groups (I prefer a group of 3 or 4 students). Since I have an average of 36 students, I kept 13 baskets on the cart. Any spare materials were kept on the bottom shelf of the cart. Students would collect the materials off the cart and then return them after the lab was completed. Think of yourself as a flight attendant! And, if you are not in a classroom with lab benches, have a group of 8 students move their desks together to form one long "bench."

*Layne Heiny*

One possible solution is to arrange with colleagues in the Science department for all five Biology classes to have at least one lesson in the same room each week, or at least in alternate weeks. This will provide for a practical lesson for each class at least once per week, although it does not provide for the optimal situation of being able to incorporate practical lessons into a teaching sequence as they are needed. The non-practical lessons should not make any difference. I teach

Physics and Chemistry and there is a teacher in my school who does not have a laboratory for her practical lessons, so I sacrifice one of my science laboratories for her use once each week.

*Subir Sinha*

When I was a travelling science teacher I used the grey trays in our department to assemble materials ahead of the class and put a “Please leave for MM” sign on them. It did require me to be sufficiently early to set up five trays a day ahead of time, but it was worth it to include practical activities in lessons. I was fortunate that each lab was reliably and permanently set up with basic equipment.

*Michele Mock, Universal College of Education, Palmerston North, New Zealand*

# Laboratory Safety Guidelines

This section presents a series of 40 laboratory safety guidelines kindly provided by Dr James A. Kaufman, President, The Laboratory Safety Institute (LSI), USA. Please visit http://www.labsafety.org for further information, products, services, and publications.

**#14 of 40.** ***When Conducting Experiments With Hazards or Potential Hazards, ask Yourself These Questions: What are the Hazards? What are the Worst Possible Things That Could go Wrong? How Will I Deal With Them? What are the Prudent Practices, Protective Facilities, and Equipment Necessary to Minimize the Risk of Exposure to the Hazards?***

This is the world's simplest safety program. It represents the minimalist approach. If you want to know how little you can do and "get by," being able to answer these four questions is a good beginning point.

Can you identify the hazards that are present? Are they chemical, physical, biological, mechanical, electrical, radiation, noise, stress, or high/low pressure? Those are life's nine hazards and you should look for them before beginning an experiment.

What kinds of emergency situations can you anticipate? Fires, explosions, electrical shocks, bleeding, burns, cuts, poisonings, slips, trips and falls, spills, extreme weather, medical problems, workplace violence, and natural disasters should be considered. What about other medical emergencies and utilities failures. And, everybody’s favorite, a colleague who goes “postal.” Are you prepared to deal with these kind of problems? Do you have written procedures describing what to do?

Do you have the necessary safety equipment and emergency equipment? Deluge showers, eye wash fountains, first aid kits, fire blankets, fire extinguishers, communication system? What about gloves, goggles, and lab coats? What are the generally-recognized safety practices that a reasonable person would follow before experimenting? Carefully reading labels and MSDSs is a good beginning. Hand washing when finished is another.

Have you considered reducing the scale of the experiment, substituting a less hazardous chemical or eliminating the experiment altogether? Teachers/supervisors need to adjust the experiments so that the health and safety risks involved are appropriate for the facilities, the equipment, the experience of the teacher/supervisor, and the abilities of the students/employees. Making those decisions in the teacher's/supervisor's responsibility.

Some organizations, both non-academic and academic, have a hazards review committee and/or process. The function is to try to make reasonably sure that all the issues have been properly considered. At Dow, we had to prepare a safe operating package and have it reviewed by 2 supervisors before starting certain hazardous experiments. One copy of the package was posted on the fume hood and one filed in the front office (in case the hood was on fire!).

An Emergency Preparedness Review Checklist is available. In addition to assisting in the planning for emergency responses, this LSI publication covers many safety program topics.

# Further Useful Resources

***TimeTree: The Timescale of Life*** (http://timetree.org/) TimeTree is a public knowledge-base for information on the evolutionary timescale of life. A search utility allows exploration of the thousands of divergence times among organisms in the published literature.

***SimRiver*** (http://web.stcloudstate.edu/phytolab/srhtml/diatom.htm) Allows students to develop a river basin and identify how human activity affects producers, specifically diatoms.

***Mysterious Glowing Ball*** (http://tinyurl.com/glowball or search for this title on YouTube) A demonstration of persistence of vision using a moving ball containing a light-emitting diode that flashes from red to blue to green. When the ball is stationary, the flash rate is sufficiently high for the human eye not to be able to perceive the individual colours, with the ball appearing essentially white. Swinging the ball on a string allows the individual colours to be seen.

***PowerPoint Presentations (With Animation)*** (http://www.personal.psu.edu/lht1/) Contains an example/tutorial on the use of the Custom Animation feature of PowerPoint to animate a lecture and illustrate physical ideas, as well as downloadable presentations in the areas of mechanics and electricity. For each slide, the commands can be seen in the Custom Animation column.

# Supernatural Explanations: Science or Not?

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***Abstract***

Contrary to the advice of supposedly authoritative sources, the a priori exclusion of supernatural explanations or claims from scientific scrutiny is not appropriate. This paper shows how supernatural hypotheses or claims should be treated by science and, in the process, differentiates scientific and non-scientific hypotheses or claims. Educational strategies are provided to help reduce the widespread belief in claims that have been contradicted by scientific testing and to help students avoid advancing hypotheses that are unlikely to be supported by empirical evidence. Both science and religion appear to play a role in societies, and there need be no conflict between these two very different domains.

Students need to be provided with opportunities to apply the scientific method (or hypothetico-deductive approach) during science classes. An outline of the scientific method may be found in, for example, Eastwell (2010). During this process they will likely be asked to suggest one or more hypotheses (i.e., proposed explanations) for an observed phenomenon and test it or them. What hypotheses are acceptable for consideration in science classes? Are there restrictions? In particular, what is the status of a supernatural hypothesis in science? This paper addresses these questions and, in so doing, provides the best answer to the following multiple-choice question:

Which of the following appears to be the best choice?

A. Science cannot test a supernatural explanation or claim.

B. Science can test a supernatural explanation or claim.

C. Science can test some supernatural explanations and claims but not others.

## A Confused Landscape

My reading of the literature, together with conversations with other science educators around the globe, on the relationship between science and the supernatural has been characterised by confusing and contradictory information. I have come to appreciate how readily teachers, as a result of exposure to selective reading only in this area, could adopt what appears to be a misguided position. This would be most unfortunate, as it would impact negatively on the effectiveness of these teachers to guide student scientific inquiry appropriately.

As an additional check on the clarity, or lack thereof, of thinking in this area among science educators, I surveyed readers of *The Science Education Review* (*SER*) about the following, more concrete, scenario:

> Imagine students arriving at school after a weekend to find that plants have sprung from the soil in a pot. As part of the science curriculum, their teacher asks: "Why has this happened?" One student hypothesises that angels visited during the weekend and initiated the plant growth. Would you encourage this student to test this hypothesis as a part of doing science, or not? If yes, would you kindly exemplify how you think the student investigation might proceed. If not, would you please provide your reasoning.

The responses proved illuminating. Only 16 of the 8,000 readers on the journal mailing list responded to the survey question, with these responses split roughly evenly between the *yes* and *no* positions (some responses did not make the responder's position clear in this respect) and characterised by conflicting views. The following comment from one university educator is particularly noteworthy: "I passed that question about angels to many of my fellow faculty and they did not want to touch it. I have no problem talking about it! Interesting!" In addition, 2 readers were critical of the journal--and, by implication, me as Editor--for even asking what they perceived to be such a "silly" question in the first place. So, I hypothesised that many did not feel confident in responding to the angel-hypothesis question and that this, together with the fact that those who did respond held differing, and even contradictory, views, suggested that there was indeed an issue here that would likely benefit from deliberation and clarification.

## The Angel Hypothesis

The supernatural/metaphysical is characterised by descriptors such as outside the observable universe, violating natural laws, and pertaining to god or a deity and is commonly associated with things like spirituality, occultism, spirits, the divine, the miraculous, fairies, vampires, ghosts, goblins, and other unearthly beings, including angels. In preparing to respond to the foregoing angel-hypothesis survey question, one might first check on what is advocated on the issue of science and the supernatural by what might readily be assumed to be authoritative sources. Consider the following:

- "Supernatural entities, by definition, operate outside of natural laws and so cannot be investigated using scientific methods" (American Association for the Advancement of Science [AAAS], n.d.b, p. 12).
- "Because 'intelligent design' theories are based on supernatural explanations, they can have nothing to do with science" (Alberts [President of the National Academy of Sciences], 2005).
- "Questions that deal with supernatural explanations are, by definition, beyond the realm of nature--and hence, also beyond the realm of what can be studied by science" (Understanding Science, n.d., ¶ 5; part of a website produced by the UC Museum of Paleontology of the University of California at Berkeley, in collaboration with a diverse group of scientists and teachers, and funded by the National Science Foundation).
- "It [intelligent design] invokes supernatural causes, and … hypotheses involving reference to supernatural causes are not within the purview of science" (Fales, 2009, ¶ 5, commenting on a United States judicial ruling concerning the teaching of intelligent design in public school classrooms).

A common theme across these quotes is that science deals with the natural, not the supernatural, and so an angel hypothesis cannot play a role in science. However, this position does not appear to stand up to scrutiny. Could it not be that what at present appears to be a supernatural phenomenon might rather be a natural phenomenon that is yet to be recognised? The a priori exclusion of supernatural-based explanations or claims from science would therefore unnecessarily impede the further development of our understanding of the natural world. Surely it is better for science to keep an open mind to all possible explanations and to simply go where the evidence leads.

Further, one of the features of the nature of science is that scientific explanations and claims must lend themselves to being both empirically testable and contradictable (Eastwell, 2002). Please note that, by testable, I do not mean that, for whatever reason (e.g., a lack of technological means), the explanations or claims must lend themselves to being testable right now, but rather that they are testable in principle Therefore, a better approach to the angel-hypothesis scenario would be to ask the student to try to generate a test for the hypothesis that, in accord with the scientific method, needs to include explicitly-stated predictions that can be checked. There now appears to be three possible pathways by which to proceed:

1. The student might elaborate on his or her hypothesis in such a way as to make it empirically testable and contradictable, and now we have a scientific hypothesis. For example, the student might suggest that angels are visible entities, and one can envisage testing this by keeping a vigil or using video cameras or some other form of angel detector. Or, the student might suggest that angels leave angel dust, so once again this could be tested by searching for such dust. Or, if it is hypothesised that angels make sounds, a microphone could be used as a probe. Then, in the light of our existing scientific knowledge, after conducting such tests we expect that the student would conclude that his or her angel-based hypothesis is contradicted, thus encouraging this student to pursue alternative hypotheses for the observed plant growth that may have been suggested by other members of the class.
2. Alternatively, the student's notion of an angel could be so non-specific as to not allow a test of the hypothesis to be generated, as in the case of an angel being considered an invisible entity that does not make a noise and whose presence cannot be detected empirically in any other way. Because the angel hypothesis is empirically untestable, we would need to deem it a non-scientific hypothesis and recognise that science cannot say anything more about it. That is, science cannot reach a conclusion about (i.e., cannot support or contradict) an explanation or claim that cannot be tested. In this case, angels may or may not have caused the plants to spring from the soil; science simply cannot know.
3. In a third option, the student might elaborate by describing an angel as, for example, an entity that is capable of facilitating anything. This would again lead to the student's hypothesis being a non-scientific one because, although it is testable, it is not contradictable (i.e., does not lend itself to producing predictions that can be refuted by evidence) because it is so broad as to predict all possible outcomes.

So, explanations or claims should not be excluded a priori from science, including school science, simply because they appear to be supernatural, paranormal, or even religious in nature. Creationism and intelligent design (ID), for example, make claims that can be, and have been, tested empirically. These claims should not be dismissed from science simply because they have a supernatural or religious element and are therefore supposedly unscientific, but rather because the scientific testing has contradicted them (Fishman, 2009). For example, Lawson (1999) produced a superb lesson plan that allows students to use fossils to compare the theory of evolution and the alternative explanations of special creation and spontaneous generation and to conclude that the evidence supports the former only and contradicts the other two explanations. However, those explanations or claims that in principle cannot be both tested empirically and contradicted, such as God-based hypotheses that are so general as to explain everything (i.e., the notion that God can be used to explain the presence, or absence, of anything) need to be considered non-scientific explanations or claims about which science can say nothing more. It follows, then, that the best response to the multiple-choice question that introduced this paper is Option C; namely, "science can test some supernatural explanations and claims but not others" (i.e., science can test scientific explanations and claims but not non-scientific ones).

While acknowledging that some supernatural claims are beyond the scrutiny of science, we are left with the question of why supposedly authoritative sources such as those identified earlier in this paper advocate that all supernatural claims are beyond scientific testing. I am writing to some of these sources seeking the reasoning for their position and intend to report the responses in a future issue of this journal. Surely the rationale could not be as shallow as wanting to avoid conflict between science and religion and thus the political risk of religious taxpayers withdrawing their desire to support science financially! However, although a supernatural hypothesis such as the angel-based one considered here may indeed be a legitimate scientific hypothesis, later in this paper I will suggest two science education strategies that may beneficially result in students not being inclined to propose such a hypothesis in the first place.

## Evaluating the Probable Truth of an Explanation

If supernatural explanations can play a role in science, one might ask why we do not see them being proposed and tested more often in the science research literature. In short, it is because spending time on investigating a supernatural explanation of an observed phenomenon is unlikely to produce support for it, as I will now explain, and most prefer to devote time and effort to producing something that is more likely to "work."

Just because something is possible does not mean that it is probable. Fishman (2009) draws on Bayesian confirmation theory to provide three ways by which science can evaluate the probable truth of an explanation or claim; namely, by a consideration of:

1. The prior probability of the explanation or claim being true.
2. The empirical evidence for or against the explanation or claim.
3. Plausible alternative explanations.

If I was to claim to have a car in my garage, nobody would pay much attention. However, the claim that I had a fire-breathing dragon in my garage would likely attract much doubt (i.e., be given a low probability) because it conflicts so extremely with our present knowledge of nature and how it works. Supernatural explanations or claims are likely to similarly have low initial probabilities, particularly in light of the long history of such explanations or claims having been either contradicted and/or replaced by alternative, non-supernatural explanations, as exemplified by the following:

- Lotteries are not consistently won by psychics, thus contradicting the claim that some people possess extrasensory perception.
- There was a time when lightning was considered to be a tool used by the Gods to punish evil people, with Benjamin Franklin's lightning rod even being condemned on the basis that it was an attempt to interfere with God's will. However, the evidence suggests that lightning does not discriminate on moral grounds!
- Astrology does not make detailed and accurate predictions.
- Kepler had angels beating their wings to drive the planets forward (D. Sathe, personal communication, April 10, 2011).
- Intercessory prayer has not been shown to improve patient outcomes (Aviles et al., 2001; Benson et al., 2006).
- The biblical account of the Earth being less than 10,000 years old has been contradicted.

- Before being contradicted by the theory of evolution by natural selection, even Darwin (1876/2000) was convinced by Paley's (1802/2006) argument for intelligent design.
- According to legend, puzzled by the absence of mention of a Creator in Laplace's work on celestial mechanics, Napoleon was told by Laplace that he had no need for that hypothesis (Center for History of Physics, 2011).
- Many illnesses were once attributed to supernatural entities, and considered punishment for sins or the result of the whimsical behaviour of gods or spirits. So, for thousands of years, treatments consisted of appealing to these supernatural powers through offerings, sacrifice, and prayer. However, the introduction of germ theory in the 19th century radically changed both the explanation and the treatment (AAAS, n.d.a).

So, as time has progressed, the world has become increasingly "naturalised." Natural explanations, based on our background knowledge, are appealing because they have proven to be very effective in improving our understanding of the natural world. Most adults prefer a more mundane, alternative explanation for why the milk and biscuits disappeared than an appeal to Santa Claus. Perhaps the fact that science can have a role in commenting on the supernatural explains why the vast majority of scientists who are members of the National Academy of Sciences are atheists (Larson & Witham, 1998). All this is, of course, not to say that some supernatural explanation, or even a supernatural world view, might not come to be supported at some future time. However, with such a claim that is characterized by a low initial probability will come a very high burden on the claimant to provide convincing evidence.

## Two Useful Educational Strategies

If scientists are inclined to steer away from low-probability supernatural hypotheses, and school science investigations are supposed to mirror real science, then it would seem desirable that school students do similar. I suggest two strategies to help achieve this goal. The first is exemplified by an activity that I continue to use as I visit schools in my role as a visiting science presenter, as summarised in the following:

1. Administer the Beliefs Questionnaire, found in "How Sceptical" (2002), to students (after omitting the item about aliens having visited Earth). The items include the consequence of breaking a mirror, astrology, wearing certain jewellery to promote health, palmistry, telepathy, clairvoyance, and telekinesis and represent beliefs that can be easily refuted. Religious beliefs have been purposely avoided, not because they need be but to avoid the group becoming "bogged down" in more complicated, contentious distractions. In this way, connections to religion are left implicit.

   My experience with especially lower-secondary students is that beliefs in superstitions and supernatural and pseudoscientific claims that do not hold up under scientific scrutiny is "alive and well," which is in accord with the findings of others for not only school students but also tertiary science students and the public in general, including even science educators (e.g., Impey, Buxner, Antonellis, Johnson, & King, 2011; Martin, 1994; Preece & Baxter, 2000; Toynbee, 1998). That such beliefs are widespread throughout societies must surely reflect poorly on science education.

2. Invite students to consider how they might test some of the beliefs in the questionnaire, and steer them towards testing telepathy. Select a student (with whom I have previously met, unbeknown to the rest of the students), who will correctly read the minds of other students in the class.

3. Challenge students to design tests to determine whether this student really does have telepathic abilities or whether some kind of fraud is at play (which, of course, it is).
4. Conclude by telling students that science has contradicted all the beliefs in the questionnaire.

This activity serves the roles of promoting critical thinking, teaching how science can be used to evaluate claims, and sharing the present state of scientific knowledge about such claims. My experience is that students find the activity engaging, and that the outcomes are rewarding, as exemplified by the following recent comment by a Year 9 girl in Australia: "I don't like science, but I enjoyed this lesson. I'll certainly sleep much better tonight!"

The second strategy I suggest is to provide opportunities for students to appreciate the history of the development of our understanding in certain areas. A classic might be the story of how we came to accept that the Earth (and other planets) revolves around the Sun, including the competition between geocentrism and heliocentrism and the pressures exerted on Galileo, by the Catholic Church, for promoting heliocentric theory. Other useful areas might be disease, including how the germ theory emerged, and why the ideas of phlogiston and the luminiferous aether were superseded (Fishman, 2009).

## God-Based Beliefs

It would seem appropriate, in a paper dealing with science and the place of supernatural explanations, to devote a little space to addressing the issue of science and religion specifically, because it is topical. I preface my thoughts, though, by declaring that my background is in science and science education rather than spirituality and religion, so my comments may best serve the purpose of encouraging others with appropriate expertise to take up the conversation.

Science and religion are two distinctly different domains, with very different purposes and methods. Science is based on perceptions of our senses (i.e., empirical evidence) and attempts to understand our experiences by using testable and contradictable explanations or claims that are always tentative. Meaning in science involves bringing order to our understanding, as in the case of understanding the cause of an epidemic and how it is spread. On the other hand, religious experiences are more internal, with religion often relying on tradition, authority, and revelation and involving eternal truths that are not open to revision. Religion attempts to give meaning to our experiences and addresses more abstract questions and questions of ultimate significance.

Conflict between science and religion has typically arisen as a result of statements by religious authorities being contradicted by science. With the content of the previous paragraph as background, and in accord with the thinking of, for example, Derry (1999) and Gould (1992, 1997/2001), it seems that there is no need for conflict between science and religion, provided religion learns from history and refrains from making statements about nature that are empirically contradictable (which is the province of science) and science likewise refrains from making statements having a spiritual dimension (which is the province of religion), as in the case of the physicist who declared: "The more the universe seems incomprehensible, the more it seems pointless" (Derry, 1999, p. 127). Advancing religious/God-based hypotheses concerning the composition of the universe and how nature works that are sufficiently detailed to be contradicted is fraught with danger for religion, because this can only be setting religion up for failure. If the God-based hypothesis predicts correctly, nobody takes much notice, but if it does not, the religious teaching is contradicted, and religion does not have a self-correcting mechanism in-built as science does.

More than other cultures, the major past conflicts between science and religion have involved the Christian West, although the Koran does provide for microevolution but not macroevolution. That the lesson from history about the dangers of religion making empirically-contradictable claims has not been learned by some appears to be exemplified by those educational institutions that continue to teach, for example, that the Earth is only a few thousand years old, and I fail to comprehend the wisdom of doing so.

So, based on the foregoing, what are we to make of religious beliefs? An example might be the "God created me" hypothesis, which does not seem to be testable and hence is non-scientific, provided one does not elaborate on the nature of God in such a way as to make it empirically testable. An entity becomes testable if it can be detected or if its effects or consequences can be observed and, as Fishman (2009) has argued, as soon as one elaborates on the characteristics of God using descriptors such as omniscient, benevolent, and omnipotent (i.e., all-knowing, doing good, and able to do anything) we have a testable claim that appears to be contradicted by the evidence. Similarly, a description/claim such as God has infinite benevolence to let us learn from our own mistakes is non-scientific, because while it is testable, it is also so broad as to predict all possible outcomes and is therefore not contradictable (i.e., does not lend itself to producing predictions that can be refuted by evidence). To take one extreme, then, there will be those who hold the view that, because religious beliefs cannot be tested or contradicted, believing such is on a par with believing in any absurdity, including the Flying Spaghetti Monster (Church of the Flying Spaghetti Monster, n.d.), thus reflecting an epistemological position that knowledge can result only from hypothetico-deductive (scientific) reasoning.

However, the evidence suggests that such a position undervalues the role and value of religion in many, if not most, people’s lives. For example:

- A very small minority of the world’s population is atheist (Wikipedia, 2011a).
- I was struck by the recent testimony of Sudanese refugees on the radio about how valuable their religious faith had been in helping them to cope with the atrocities they had been forced to witness.
- Former British Prime Minister Tony Blair, who converted to Catholicism after leaving office, acknowledges that it is his religious belief that motivates him to try to contribute to the greater good rather than to personal gain alone (Monk Debates, n.d.).

Indeed, biologist Freeland (2010) is “happy to accept that humans are a ‘religious’ species, having evolved sufficient intellectual capacity to postulate the possible existence of an intelligent creator” (p. 41) and regards what some anthropologists have called our religious instinct to be “as much a part of being human as thinking logically or carrying out scientific experiments” (p. 41).

Why is it that humans typically have some sense of spirituality and some form of supernatural worldview, even in the absence of support for their beliefs from scientific testing and, what is more, the long history of supernatural claims that can be tested having been contradicted? Why does the notion of God persist? Why is the Pope, for example, still doing good business? Various hypotheses have been advanced, including the following described in Fishman (2009). Perhaps we have a subconscious desire for attachment and security. Perhaps we have an emotional longing for the care provided by our parents during our infant years. Perhaps the potential of religion to alleviate anxieties and fears offers powerful motivation to believe. Perhaps religious rituals and prayer provide an apparent degree of control over events. Perhaps inferring the existence of supernatural entities is a by-product of processes that evolved to assist survival.

The natural inclination of humans to believe in supernatural entities, or at least be prone to acquiring such concepts from their culture, is not universal, though. The saying that “there are no atheists in trenches/foxholes” is “used to argue that in times of extreme stress or fear, such as when participating in warfare, all people will believe in or hope for a higher power” (Wikipedia, 2011b, ¶ 1), but the evidence contradicts this. For example:

> Joe Simpson, author of the book *Touching the Void*, explicitly addresses the issue in the film adaptation of his nearly fatal climb of the Siula Grande mountain. Referring to the moment he lay at the bottom of a deep crevasse, dehydrated, alone and with a broken leg, he states: “I was totally convinced I was on my own, that no one was coming to get me. I was brought up as a devout Catholic. I'd long since stopped believing in God. I always wondered if things really hit the fan, whether I would, under pressure, turn round and say a few Hail Marys and say ‘Get me out of here.’ It never once occurred to me. It meant that I really don't believe and I really do think that when you die, you die, that's it, there's no afterlife.” (Wikipedia, 2011b, ¶ 9).

Both science and religion can be used for good or for evil, and both scientific and religious experiences appear to play a valid role in societies, although their relative validity is a matter for personal determination, perhaps not unlike how, for example, some will view a wind farm as an aesthetic beauty while others will view it as an eyesore. I do not have difficulty with others having spiritual beliefs that they find helpful, but do draw a sharp line when, for example, a group wants to exterminate the rest of us who do not share the same view!

In summary:

- All explanations and claims, including those that appear to be supernatural, paranormal, or religious, should be open to scrutiny by science.
- Explanations or claims that in principle cannot be tested empirically because they lack specificity are non-scientific explanations or claims. Science cannot reach a conclusion about (i.e., cannot support or contradict) an untestable explanation or claim. Explanations that are testable but not contradictable are also non-scientific.
- Science education has a duty to teach students how to distinguish scientific claims (i.e., those that are both testable and contradictable) and non-scientific ones, and to make an impact on reducing the widespread belief in claims that have been contradicted by scientific testing.
- There is no need for conflict between science and religion, provided religion does not make statements about nature that can be empirically contradicted (which is the province of science) and science does not provide commentary having a spiritual dimension.
- Both scientific and religious experiences appear to contribute to the human experience, although their relative validity is a matter for personal determination.

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