Physical Geography: Learning and teaching in a discipline so dynamic that textbooks can’t keep up!

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ABSTRACT: Physical geography is a dynamic discipline. This makes geography exciting, but poses some problems for teachers and students. Learning resources rapidly become out of date, and some of the resources that students and teachers trust are in fact seriously flawed. Students progressing from A-level to university are often confronted with the realisation that much of what they studied at school was outdated or incorrect. Fundamental problems for teachers of physical geography include keeping up to date with new discoveries, choosing reliable teaching resources, and knowing what to tell students when resources provide conflicting information. The situation has been made worse because some of the most widely used textbooks and websites, which most students and teachers trust, are perpetuating dated or incorrect ideas and information.

Using the teaching of global environmental change and glacier systems as an example, this article illustrates these problems and suggests a number of possible solutions. Although the article focuses on specific examples, the problems and opportunities illustrated here apply across the whole discipline.

Problems for geography students and teachers

Geography is a fantastic subject, encouraging us to explore and understand the world around us. It gives students the opportunity to encounter places and environments locally and globally, to combine a range of skills in fieldwork and classroom study, and to identify links between aspects of the natural and human environment that other subjects often study in isolation. The subject-matter of geography is highly topical in terms of current affairs, and geography students can apply their learning to a wide range of important social and environmental issues. For example, in physical geography, issues such as global warming, the collapse of the world’s glaciers and the catastrophic rise of global sea level feature almost daily in the press and on the television news, giving students a broader cultural context to their geographic studies. In the degree course in physical geography that I teach at Keele University, we use the theme of global environmental change as the focal point around which the course is organised, partly because it is a topic that students find appealing and
accessible, but also because it provides a way of
drawing together a wide range of different types
of geographical evidence to address an important
issue. Geography is all about combining evidence
from different sources to address complex inter-
disciplinary topics and problems. Environmental
change, ice-sheet collapse and global sea-level rise
are among the most complex, and the most
pressing, geographical concerns.

However, although geography students and
teachers are blessed with interesting topics to
study, it is a mixed blessing: these topics are also
the focus of ongoing scientific research. In one
sense, this is a bonus for geography teachers as
it enables us to explore a whole range of issues to
do with the dynamic nature of the discipline.
However, a problem for us as teachers is that our
knowledge and understanding of the world
is gradually changing. In fact, the rate of change is
not always gradual. Environmental change,
glaciology and oceanography, and the other
sciences concerned with matters such as sea-level
change are moving very rapidly. New findings are
published on a weekly basis in major international
journals such as *Nature* and *Science*. This means
that teachers who studied for their degrees even
very recently may struggle to keep abreast of new
developments, and sources such as the BBC
and other news media often present an
oversimplified or partially outdated version of our
rapidly developing knowledge. The fast-moving
research frontier makes it exciting for students
to learn, but hard for textbooks and teachers to
keep up. How can we stay abreast of new
discoveries? How should we choose reliable
teaching resources? How do we judge conflicting
sources of information in the media? These
problems are made worse because very few of the
most popular and well-respected textbooks and
media sources contain consistently reliable and
up-to-date information. The following case study
will illustrate this.

**Case study: glacier flow,
erosion and drumlins**

The origin of drumlins, a type of depositional
landform associated with glaciers, is a traditional
topic of study at all levels in geography, so one
might expect textbook explanations of drumlins
to be clear, correct and consistent. However,
partly because drumlins continue to pose
problems for researchers at the highest level,
This statement is fundamentally flawed. In a glacier, competence to carry a load is not related to velocity as it would be in a river, and an increase in load does not lead to a change in competence. Because glacier motion is different from water flow, processes of sediment transport and deposition are also different. Unfortunately, perhaps because so many teaching resources draw information from each other without reference back to a source or sources of reliable information, this fundamental misrepresentation of physical process is repeated in a large number of teaching resources. For example, the BBC ‘SOS Teacher’ website states that:

Lodgement till … is the material that is deposited under ice while the ice is moving. This action is almost like smearing and occurs when the weight of material becomes too great to carry on by the glacier. Features created by this deposition include drumlins' (http://www.bbc.co.uk/schools/16/sosteacher/geography/49085.shtml).

This flawed assertion repeats the same fundamental error that is made by the textbook. Similarly, errors are evident in widely used information about other aspects of glacier behaviour. For example, concerning glacier flow, one popular revision website claims that Ice erosion … involves three processes: 1. Plucking, 2. Glacial abrasion, 3. Sapping’ (http://www.revision-notes.co.uk/revision/187.html)

This bears little relation to current understanding of glacier processes. ‘Plucking’ has been shown to be a process of limited effectiveness, because the bond between an ice mass and the rock to which it is frozen will usually be weaker than the rock itself. This means that the ice is likely to pull away from the rock before the rock itself is fractured by the tension exerted by the ice. The notion of plucking has been superceded by the concept of ‘fracture and traction’, with most attention being given to the mechanical process of subglacial fracture. Sapping (a freeze-thaw process) is not a process of erosion at all and should not be in this list!

The same website provides an equally flawed list of the mechanisms by which glaciers move, citing ‘plastic flowage, basal slip and internal shearing’, with no mention of subglacial deformation. In the 1970s a major revolution occurred in our understanding of glaciers when it was recognised that many glaciers move primarily as a result of a deforming bed, where sediment beneath the glacier becomes mobile. Subglacial deformation has been a major part of our understanding of glacier motion for more than 30 years, and yet it is still largely ignored by A-level teaching resources! Thus, while there are indeed three main sets of mechanisms by which glaciers move, they are not the mechanisms cited by revision-notes.co.uk. Instead, they are 1. basal sliding, 2. ice deformation, 3. subglacial deformation.

Opportunities as well as problems

While outdated material in flawed teaching resources is clearly a major problem, there is a silver lining to this particular cloud in that it presents opportunities as well as difficulties. Part of the reason for the problems we face is that the science behind physical geography is still active. We are finding out new things all the time. That is a good thing. However, if a textbook we are using contains out-of-date material, we can use it as an opportunity to discuss with students a new discovery in the subject. This in turn is an opportunity to discuss the nature of science, the idea that science is dynamic, and the idea that all knowledge is provisional and subject to modification. These are important issues that most students emerging from the A-level system have entirely ignored. When students arrive to study geography at university, they are usually very surprised to discover that there are things about the world that are not yet understood. This is a serious failing of our A-level system that should be addressed as a matter of urgency.

Case study: global warming and glacier fluctuations

The relationship between global warming, melting of glaciers and prediction of future sea-level rise is one of the most topical issues in physical geography. The relationship between climate and glaciers is extremely complex and interesting, but the popular media, and most A-level textbooks, grossly oversimplify it, presenting the stereotypical ‘global warming causes glacier melting’ picture. When the television news contains a report on glacier retreat it frequently includes a statement such as ‘this retreat is a sure sign of global warming’. However,
glacier retreat (or advance) can actually be caused by a range of factors that are not connected to modern-day climate change, some of which are listed below.

**Changing basal friction**
If the water pressure in the ground beneath a glacier increases, for example because of changing groundwater conditions, the friction at the glacier bed will be reduced. This will cause the ice to flow more quickly, which, in turn, can cause the ice margin to advance. In the opposite situation, where the basal water pressure is reduced, friction increases and the glacier slows down. This slowing down of the ice can cause a retreat of the margin that is entirely independent of climate change.

**Migrating ice divides**
The amount of ice being moved through a glacier depends on the size of the glacier’s catchment area. Just as a river with a big water catchment area will have more water in it, so a glacier with a big ice catchment area will have more ice flowing through it. On an ice sheet from which many glaciers drain outwards from the centre, the position of the ice drainage divide (at the summit of the ice sheet) can move over time if the distribution of snowfall varies. This causes the size of the catchment areas of some glaciers to grow, and of others to shrink. Even if the ice sheet as a whole is constant or growing, some glaciers might experience a reduction in their ice supply and therefore retreat, completely independently of climate change.

**Floating glaciers**
Where a glacier flows into a lake or the sea, for example in the case of a fjord glacier or a marine ice shelf, a change in the position of the floating ice margin is a very unreliable indicator of climate change because the position is largely controlled by the topography (and bathymetry) of its surroundings. Ablation from floating margins is achieved mainly by calving of icebergs. The amount of calving depends on the width of glacier margin at the front where calving occurs (wider

Figure 2: A floating glacier terminus in southern Iceland. In situations where ablation is dominated by calving, factors such as the water depth and the width of the floating terminus (which control calving rate) are major controls on glacier fluctuation.
glaciers can shed more icebergs than narrow glaciers) and on the depth of the water (more icebergs calve in deeper water than shallower water). In a situation where a fjord is deeper or wider inland than at a point nearer to the sea, then if a glacier starts to retreat even a small amount in response to a decrease in ice supply, it will keep retreating until it reaches a section of the fjord where the width and depth are greater than at the margin's previous position. The retreat will only stop when the margin goes all the way inland to a point where the width and depth are less than at the original position. The extent of the retreat is not climate related, but related to the topography of the fjord. Ice shelf collapse can follow a similar pattern, in that the amount of ice lost does not reflect the amount of climate change that caused the retreat.

Delayed response to ancient climate change

If the amount of ablation at a glacier margin increases because of climate change, the margin will respond quickly by retreating if the amount of ablation is greater than the amount of ice being supplied from upstream. In this case climate change has an instant and direct effect. However, ice can also retreat if the amount of ice supplied to the margin decreases, even if the ablation remains constant. In that situation, the driving force behind the retreat is a reduction in snowfall high in the accumulation area. However, in the case of a large glacier, such as the Greenland ice sheet, it can take hundreds of thousands of years for the effects of changing accumulation to travel through the glacier all the way from the accumulation area to the margin. A retreat of the margin in these circumstances therefore reflects climate change in another location (the interior of the ice sheet) at another time (hundreds of thousands of years ago).

What these examples tell us is that glacier retreat in any particular case might be caused by global warming, or it might be caused by some combination of several other factors that have nothing to do with climate. These other factors, although very important to our interpretation and prediction of glacier behaviour, are rarely mentioned in the media or in A-level textbooks. A negative response to this could be to say that the world is too complicated to understand clearly and that our textbooks are inadequate. A more positive response, and one that works well in my own teaching, is to say that the world is even more interesting than the textbooks tell us it is!

Ways forward

What I hope this article has shown is that we as teachers should try to turn some intrinsic problems into opportunities. As a starting point, I suggest the following as straightforward ways in which individuals and small groups of geographers can address some of the problems that this article has addressed. First, we can produce more textbooks that bridge the gap between school texts and research-informed university texts as illustrated by the Geographical Association’s Changing Geography series. Second, university departments can offer, and schoolteachers and students can take advantage of, opportunities for greater interaction between schools and universities. At my own university, for example, we welcome individual teachers or groups of teachers to come and learn about the latest developments in physical geography research that they can then disseminate to their students. We also welcome visits from groups of students with their teachers who want to learn about ways in which ideas or topics in their syllabus can be taken a little bit further. Third, there is a great opportunity for teachers and professional physical geography researchers to collaborate and combine their expertise to produce new teaching resources. Together, I am sure we can produce materials that will educate and inform students by providing up-to-date and reliable information that neither oversimplifies nor underestimates our exciting and amazing world.

References

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www.bbc.co.uk/schools/16/sosteacher/geography/49085.shtml (last accessed March 2006)

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