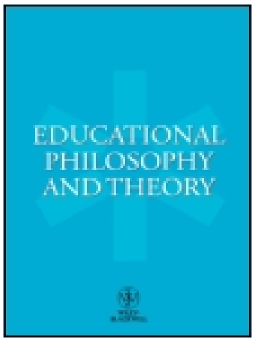

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Affirming the Consequent: or, how my science teachers taught me to stop worrying and to love committing the fallacy

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Introduction

Michael Matthews' latest book, *Time For Science Education* (Matthews, 2000) is one of those all-too-rare works which demonstrates that philosophy of education is a worthwhile and important undertaking. Matthews' book is not, itself, philosophy of education as readers of this Journal would recognise the discipline; rather it is an exquisite and consistent exercise in both applying a philosophical approach to an educational issue and in promoting the application of philosophy (and history) to teaching and learning science. Given that assessment, then, it might seem churlish if I now ignore all but a paragraph of Matthews' book—but this was not intended as a Book Review—and instead fix my sights on one passing statement of Matthews, which just happens to touch some long-exposed raw nerves of mine.

In the process of (rightly) bemoaning the paucity of basic thinking and reasoning skills with which so many of our youth leave six years of secondary school, Matthews writes (pp. 9–10; for convenience in my following argument I have added the letters (A) and (B)):

> The problem is exemplified in a small Australian study by Gordon Couchard (1989). He gave a brief, ten-item, logic test to first-year science students at an Australian university. Among the items was this one where students had to fill in the conclusion:
>
> (A)
> If one adds chloride ions to a silver solution then a white precipitate is produced.
> Addition of chloride ions to solution K produced a white precipitate.
> Therefore ____
>
> Out of a group of 65 students, 48 concluded that solution K contained silver. Thus nearly $\frac{3}{4}$ of a group of high-achieving high school graduates who had studied science for at least six years went along with fundamentally flawed reasoning. The majority of these students, despite 12 years of

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schooling, happily committed the logical fallacy of affirming the consequent; comparable results were obtained by Ehud Jungwirth (1987) in a larger, more international study of science students' reasoning skills. Little wonder that as citizens they are easily swayed by arguments such as:

(B)
Communists support unionism.
Fred supports unionism.
Therefore Fred is a Communist.

In this paper I want to examine three related things: (i) how did the situation described in example (A) come about?; (ii) does it matter generally, and with regard to science teaching in particular, if we occasionally or even frequently affirm the consequent *in certain types of cases*?; and (iii) does affirming the consequent in some cases lead people as citizens to be easily swayed by arguments such as (B) and then make 'Fred is a Communist' type conclusions about the world?

Trickery at Hand

I argued some 20-odd years ago that all our knowledge statements, including answers to questions, are to some extent context-determined; and in the course of doing so I provided a minor but nevertheless significant example (Harris, 1979, pp. 27–8) which there is point in recalling and elaborating on here. I suggested in my 1979 book that if we asked people three questions in quick succession, namely, 'What do we call a funny story that one person tells to another?', 'What do we call the black substance given off from a fire?', and 'What do we call the white of an egg?', the chances were pretty good that the answer given to the third question would be 'the yolk', and that this answer would commonly be given by people who were well aware that the yolk is the *yellow* of the egg. I also suggested that people proffering 'the yolk' as their answer might accuse us of tricking them, and that in a sense they would be right to so accuse us, since indirectly and with no specific instructions we nevertheless set a context in which the third question was to be answered. Following that publication I have performed this 'experiment' on hundreds of teachers and teacher-trainees who have found themselves in my postgraduate and undergraduate classes, and I have asked them in turn to try it out on their friends and particularly on classes at their schools. I have kept no statistical data on the results, but trust me, it almost always works (if you don't trust me, try it yourself).

Success with this has led me to refine the 'experiment' a little. I have found that, while in the above situation people are very likely to identify the white of an egg as the yolk, they are far less likely to do so when asked simply 'What do we call the white of an egg?', and in my experience they never do so when the question is put to them thus: 'The yellow of an egg is known as the yolk, but what do we call the white of an egg?'. My point is the simple and unsurprising one that questions tend to be answered, at least in part, in reference to and in terms of the way they are phrased and the context in which they asked.

This now takes me back to Couchard's item, the results of which so alarm Matthews. As Couchard's report lies in an unpublished conference paper I cannot fully examine one aspect of the context of the item and its asking. But a second aspect is patently clear. Couchard has set this item of his *logic test* in the broad context of 'science knowledge' and in the more specific context of the universally taught 'test for silver', each of which we might reasonably expect his subjects, namely 'first year science students at an Australian university', to respectively respond to and to step or fall in to (for those who may have missed out on this bit of knowledge, you test a solution for silver content by adding chloride ions [I continue to use Couchard's words] and watch for a white precipitate to form). Thus, even though the 48 students who answered 'Therefore solution K contains silver' certainly *were* committing the fallacy of 'affirming the consequent', they were also making what I would regard as a reasonable and sensible response, given firstly the context of test conditions and secondly what is in fact a form of trick question. The question suggests, although not explicitly, 'think science' (just as my question suggested 'think of a word rhyming with "smoke" '), it then prompts the respondent to recall the 'test for silver'; and finally it demands that the respondent 'fill in the conclusion in the given space'.

But there is far more to labelling the question a 'trick' question than that. Adding to the trickery is that the question is a familiar one framed in a familiar manner, but framed in such a way that the very familiarity springs the trap. And adding further to the trickery, what we have is a question *which has to be answered* (this is a test, after all) but a question for which there is no positive answer, and for which no 'confident' conclusion might be filled in, except the 'trap'!

Let me take the third matter first. What correct answer might a student write after the inviting 'Therefore ____'? One possibility is 'solution K might contain silver'. But this is very wishy-washy and not much of an answer at all, especially in context. The student might just as reasonably have concluded that the solution might contain talcum powder. Another possible correct answer is 'Therefore one can *conclude* nothing'. But as with the first possibility, this is not the sort of *on-the spot answer* first-year university students are likely to offer to a university researcher, and furthermore in a logic *test*; nor do either of the above correct answers seem to be the sort of answers *science* students are likely to give to a *scientific question* about the test for silver. At this point I have sympathy for those who sought both to give an answer and to give one germane to the test for silver; I thus have sympathy for the mass rush to affirm the consequent.

Now for the matter of trickery through familiarity. Consider how the item would have had to have been reconstructed in order to make the context-prompted conclusion 'Therefore solution K contains silver' correct. The original phrasing (A):

> If one adds chloride ions to a silver solution then a white precipitate is produced.
> Addition of chloride ions to solution K produced a white precipitate.
> Therefore ____

would have to be changed whereby, in the first premise, the consequent—silver—

needs to be shifted from the 'if' part to the 'then' part. The question would then have looked like this:

(C)
If one adds chloride ions to a solution and a white precipitate is produced, then the solution contains silver.
Addition of chloride ions to solution K produced a white precipitate.
Therefore

In this case the fallacy is not only easily averted, but also rather difficult to commit. The conclusion 'Therefore solution K contains silver' just rolls out.

But it isn't quite that simple. There are at least two problem involved in the above 'rewriting'. Firstly; the rewritten initial premise, with its grammatical and its empirical conclusion (the production of the white precipitate) in the middle rather than at the end, rings strange. We tend not to talk like that. And secondly, the very procedure described in the rewritten premise rings very strange indeed in the real world of science teaching and science learning. In that world, rather than the world of university logic tests, we tend, quite rightly and sensibly, to speak, denote and describe in terms of the initial premise found in (A). Those familiar with science, and more so with the test for silver, would have been familiar with the initial premise as written by Couchard, and were thus nicely set up for a fall.

Teaching and Learning Science

I want, now, to move from logic tests to the science classroom, and to consider the teaching (and learning) of the test for silver in a solution; and then later, purely to simplify the premises and make the matter more familiar, consider also the test for an acid solution.

The question I want to begin with is how one might possibly teach that, *strictly following the wording of the non-trap premise—C*, 'if you add chloride ions to a solution and a white precipitate is produced, then the solution contains silver'? You could write it on the board, and get the kids to copy it down and learn it. But that's hardly the sort of science teaching, learning and thinking that Matthews (or, I suspect, any decent educator) is seeking. The problem now is that you may have come to a dead end, or to the sort of impasse that, as a science teacher, you may not want to reach. When you test for silver in the real world you don't go adding chloride ions to random solutions, wait for a white precipitate to appear in one of them, and then declare that silver is present in the solution. You could add chloride ions to any number of solutions and show that only one produces a white precipitate, but then you would have to show that that particular solution contained silver ... and how would you know it did unless you had previously added silver, tested as silver, to the solution? The problem is that moving 'silver' from the 'if' to the 'then' part of the statement tends to nullify experimental and practical procedures which serve as a *test* for silver and which can be readily carried out in the context of a school science laboratory. In fact, to demonstrate a *test* for silver, science teachers might not easily be able to avoid beginning with the original form of Couchard's item (which I have labelled the *familiar* form): 'If one adds chloride ions to a silver solution then a white precipitate is produced', and then add the appropriate ions to a number of solutions, noting that the solution already identified as a silver solution produces a white precipitate. It may not be perfect; but it does describe what happens in the order that it happens—if one adds chloride ions to a silver solution then a white precipitate is produced—which, although it might invite committing of a logical fallacy, not only makes sense to kids but also just happens to be true. More importantly, it also just happens to be the way we normally, commonly and sensibly state the issue: Couchard's initial uncontrived, familiar statement inviting an empirically true response, becomes purely and simply a trap for bringing on a logical fallacy!

Let me run through this again and, if necessary, try and make it a little bit clearer by changing to a simpler (fewer clauses) and more familiar example—the litmus test. As every secondary schoolchild knows, or should know, we test a solution for acidity by sticking a piece of litmus paper in it: if the paper turns red then the solution is acidic.

The empirical and pedagogical issue before us, now, and let us be very clear about it, is *to test a particular solution for acidity*. But before we go ahead as science teachers and have our class stick bits of litmus paper in solutions, let us first act as philosophers/logicians, and write down the situation and see what happens logically rather than empirically.

Given that we know either: (1) 'acidic solutions turn litmus paper red'; or (2) 'litmus paper turns red when placed in acidic solutions'; and given that our test *is for the acidity of the liquid and not for the redness of the paper*, so that the conclusion should be 'Therefore this solution is acidic', how do we write this?

Our first try can be:

(D)
If a solution is acidic it will turn litmus paper red.
This solution turned litmus paper red.
Therefore this solution is acidic.

Now this will be readily recognised by philosophers, although perhaps not by young schoolchildren, as a classic case of affirming the consequent: {if p then q; q; therefore p}. So, how do we get round it?

One way is to change the second premise, and with that the conclusion:

(E)
If a solution is acidic it will turn litmus paper red.
This solution is acidic.
Therefore it will turn litmus paper red.

Here the logical fallacy has been averted, but at the cost of assuming (or hypothesising) the conclusion we are really after, and instead reaching a conclusion where it appears the test has been for the coloration of the litmus paper.

A second go will reveal a better solution:

(F)
If litmus paper turns red in a solution then the solution is acidic.

Litmus paper turned red in this solution.
Therefore this solution is acidic.

Now there are no logical problems, given that this is a clear case of {if p, q; p; therefore q}; and there appear to be no empirical or experimental problems either. We can start the lesson with the first proposition, give the kids their solutions and bits of litmus paper, let them do their dipping, happily watch their faces light up as the litmus paper changes colour, and with a clear logical conscience let them draw the conclusion that 'this solution is acidic'.

Doing so is good, careful, accurate logical science teaching. So, 'what's the problem?', some might be asking.

Actually there are two problems. The first is trying, or even contemplating attempting to teach young children, excitedly waiting to immerse their litmus paper in a mystery solution, that there is a real, serious and important difference between (D) and (F)—a difference that might be lying in wait to trap them years later in a university logic test.

As a teacher I'd be more concerned with maintaining interest and fostering delight rather than chopping logic. There is, of course, good reason on the one hand to approach this, and all experimental and theoretical work, in the manner of (F). But there is also good reason not to be unduly bothered about it. I shall indicate later that little, if anything hangs on whether pupils are taught either (D) or (F): here I simply stress the practical heuristic point that by making a big deal out of the properness of (F) the science teacher is going against real-world experience and thus dangerously approaching committing a more cardinal sin of divorcing science from reality and from the kid's experience of the world.

This is the second problem. If we ask why the litmus paper turned red, the answer is because solution A was acidic. And we know solution A was acidic because we dipped the litmus paper in and it turned red—and accepting that is the same as accepting either or both of the conclusions from (D) and/or (F). Doing it the 'right' way, and the scientific way, (F) rather than (D), seems to be doing it somewhat differently from real life, which might account for why so many kids don't do well in science, don't like science, or think science is all a bit removed from normal living.

Following the logic of (F) is not the way we normally or commonly do or conceive things in the real world of day-to-day problem solving. If we want to explain or account for the kitchen light having come on, and knowing that flicking the kitchen light switch turns on the kitchen light, we could conclude:

(G)
If somebody flicks the kitchen light switch the kitchen light goes on.
The kitchen light just went on.
Therefore somebody flicked the kitchen light switch.

Oh dear! That's {if p, q; q; therefore p}. Somebody has just fallaciously affirmed the consequent. But in the real world down there in the kitchen, in all probability somebody actually did flick the kitchen light, and in all probability the only normal actual real common way of getting the light in the kitchen to go on is to flick the switch (yes, it could have been spontaneous incandescence of a tungsten filament, but it wasn't), so why get all bothered about it? My point is that in real everyday experience we commonly and frequently go around affirming the consequent, and on so many occasions we still get things right and live happily and harmoniously with the world. Given this, it seems strange, if not perverse, for a science teacher to let logical matters of this particular lack of magnitude get in the way of good exciting teaching and learning. Unless, of course, there was serious trouble ahead ... a point I'll get to now.

Does it Lead to 'Harder Drugs'?

In very many cases of everyday experience in the real world, and in the school and other science laboratories in that world, sometimes (D) and (F) type formulations and approaches serve us equally well, sometimes it is not necessary for us to differentiate or choose between them, and at other times (D) type formulations seem (all things considered) better suited for the job. The question, then, is whether or not it matters if we go about, on occasions, preferring (D) type formulations and subsequently affirm the consequent in particular instances.

It certainly would matter if it followed, as a matter of course, which Matthews with his 'little wonder' seems to think it does, that those tricked by the wording and contextualisation of Couchard's example then went on to believe that Fred is a Communist because, like Communists, Fred supports unionism.

There is no evidence, however, to indicate that people affirming the consequent in one situation will then go on to do so in another situation or in all situations. And this takes me back to the matter of context. In Couchard's complex example set in a particular context, 48 out of 65 students fell for a well-laid trap. I have no empirical evidence, but I do have a real gut feeling, that not many of the 48 would, in (B), declare Fred to be a Communist.

I get this gut feeling from experience, a small amount of empirical support, and from the knowledge that committing the fallacy of affirming the consequent, being partly context-driven or dependent, varies considerably with the content provided in the premises. If the conclusion doesn't make sense, people tend not to commit the fallacy. I have done some work with science teachers and intending science teachers which shows that those who merrily base their teaching on (D) type formulations:

> If a solution is acidic it will turn litmus paper red.
> This solution turned litmus paper red.
> Therefore this solution is acidic.

do not, as a rule, go as far as accepting the following 'conclusion':

> (E)
> Tables have four legs.
> My cat has four legs.
> Therefore my cat is a table.

I suspect there might be more value in researchers seeking to learn in what cases and circumstances people commit the fallacy of affirming the consequent, and to what extent committing the fallacy generalises in people's behaviour, rather than laying traps where the fallacy is very likely to be committed, as a prelude to themselves claiming the moral/logical high ground.

Conclusion

I do not question that affirming the consequent is a logical fallacy, or that committing the fallacy can have some unfortunate consequences. I am most unsure, however, that it follows that someone who commits the fallacy in one situation, especially a trick situation, will then commit it again in all or most situations. And when it comes to science teaching, in those cases where it matters little whether the fallacy is committed or not but where it might matter to some degree how a question or an experiment is put to a class, given that there seems to be little worry about generalising or reinforcing commitment of the fallacy, I would go for courting the fallacy every time if it meant kids came to learn, and maybe even love science.

A long time ago at school I learnt the test for hydrogen (it extinguishes a lighted taper with a soft 'pop'). My teacher told me that if hydrogen is present it extinguishes a lighted taper with a soft 'pop'. She then gave me (and all the others in the class) a lighted taper. I applied it to gas coming out of a flask and there was a soft 'pop'. I concluded that there was hydrogen present. Notwithstanding that I had committed the fallacy of affirming the consequent at the time, I came to love science and doing tests like that. And I have also come to know full well that Fred is not a Communist just because, like Communists, he too supports unionism; and I am absolutely certain, notwithstanding the fact that he has four legs (*and* spends much of the day in the dining room), that my much loved Felix is not a table.

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