The use of mathematics in ks3/ks4 science classes

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In this study I interviewed five science teachers about the use of mathematics in their classes and four maths teachers about their use of mathematics and their view of mathematics in science. I look at the distinction between the maths and science departments and differences that occur in the two settings as described by the teachers. I also look at the factors that contribute to the separation of the disciplines in school and the pressure exerted on teachers by the national curriculum and exams. Finally the teachers describe areas where students have difficulties using mathematics, and how this might relate to the separation of mathematics and science. I then discuss possibilities for further exploration of this separation.

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Mathematics and science as separate disciplines

In an interview of nine mathematics and science teachers about the use of maths in science classes, the message that emerged was that of a distinct separation of mathematics and science in school. This was evident in the way teachers discussed the lack of coordination and communication between departments, and in the more implicit descriptions of the school disciplines as separate, independent subjects. As a consequence of this separation the teachers described differences in the style and in the terminology that was used in mathematics and science classes. The teachers acknowledged that these inconsistencies created potential barriers to understanding between maths and science for their students. Teachers also noted that their students saw their science and their mathematics classes as being independent, and therefore had certain expectations for each class that could affect their performance when mathematics concepts did arise in a science class.

All of the teachers agreed that there was a lack of formal dialogue between the science and mathematics departments at all of their current schools. Each department had its own agenda and the need to meet and coordinate within the department was prioritised over inter-departmental communication. Most of the teachers however did think that a formal dialogue could be beneficial, particularly in terms of coordinating specific topics between departments. Robert as head of his school's maths department commented on an informal conversation he had had with a member of the science department,

> He said that they taught subject x in year 7 but we didn't get there till year 8 or 9 whereas, given that probably maths should facilitate them we should be doing it earlier and think about that so we can help them.

In addition to the concern about coordinating topics, coordinating terminology and even teaching styles came up as well. Examples of terminology that varied between departments were 'standard form' versus 'scientific notation', 'ratio' versus 'proportion', 'independent' versus 'input' and 'dependent' versus 'output'. Teachers

who were aware of different terminology in the maths and science departments at their schools felt that it was important to make their students aware of the different terms, and to explain that they were often used to mean the same thing. They claimed that the difference in terms otherwise would confuse their students.

Other differences seemed more ingrained in the disciplines rather than simply in the individual departments. One aspect that came up in a few interviews was the use of different symbols in mathematics and science. In explaining gradients in physics, some of the teachers referenced the standard symbols y=mx+c and for rearranging equations a=b/c. These references to common symbols in maths seemed to help some students. Anthony (science) described the way he would check for understanding in the rearranging of equations and the importance of making sure students understood the consistency of mathematical concepts when different symbols or terminology were used:

> So you say "look, we know R and we know T the time constant, can you calculate the capacitance girls?" And they'd say, "yeah, you do T/R" And again they know how to do it. I'd say, "just tell me what your maths teachers told you? cause I would call it cross-multiplying." And you'd get the nod from the girls, ah good. So we use the same, so language is important. Checking use of language…And I think you should trigger in the girls, "remember in maths you may have come across this sort of thing, Y is MX, therefore X= Y/M type." And if the girls can make that link, then it's not an issue.

Other differences between mathematics and science resulted from the teaching materials and the exams that students were given in each discipline. Darren (maths) noted the use of words versus symbols in the equations in the science textbooks, a style of formula in science that surprised many of the maths teachers.

Other maths teachers mentioned lines of best fit, which in science classes were sometimes straight and sometimes curved but for GCSE maths were always straight lines. Seth (science) in his chemistry class found this view from mathematics moving across into science, "they tend to draw a straight line, and always assume that line of best fit has to be a straight line." Maths teachers reported the opposite, finding that students would sometimes bring in curved lines from their science classes when they were not appropriate to the mathematics.

A few of the teachers did discuss some mathematical concepts that they did not feel belonged strictly to one discipline or the other. The struggle with how to classify certain topics as maths or science came down to where the responsibility should lie for teaching those topics. Frieda (science) mentioned for example selecting the appropriate graph to use with a data set. When she first began teaching she had expected her students to be proficient in this from their maths classes. However she found that she had to teach this every year in her science classes, and that much of teaching this skill had to do with the interpretation of the data. In that respect she felt that science class might be the more appropriate place to teach about interpretation.

The need to assign topics to either mathematics or science is something that Bernstein (1971) discusses in terms of classification and framing in school. He claims that classification creates boundaries between disciplines and insulates them as specialised subjects. Bernstein (1971) argues that this creates a socialised 'subject loyalty' for both teachers and students as they hold on to their identity as given by their specialised subject. This is seen in some of the teacher interviews in comments about differences in style. Robert (maths) gave an example of sometimes needing to tell his students, "in maths we do it this way," drawing a difference between maths and science that indicates that even where there might be an overlap in content, there still is a distinct way that scientists and mathematicians do things. Furthermore

framing maintains these boundaries, creating the need to assign certain topics or applications to one discipline or the other rather than allowing for connections between the two subjects.

Creating the separation

The classification and framing that was described by the teachers seemed to be created or maintained, at least in part, by the exam driven nature of their teaching and of the set curriculum. In discussing the differences that existed between the two subjects and the barriers to integration, both in styles of practice and in student understanding, the role of exams and of the national curriculum came up again and again.

Exams

From the comments of the teachers in mathematics and science, it seemed that exams played a distinct role in determining content, timing and even teaching style. The importance of their students' performance on the national tests meant that the focus of their teaching had to be on tested material. Darren (maths) stated:

> Ultimately we are looking at preparing the kids for the exams. And so the, your sort of, your bias in terms of where you direct their attention is formulated largely by what your expecting for that in the future.

Thus the fact that teachers saw particular topics as being their responsibility, and others as being the responsibility of teachers in their other subjects, was facilitated by the demands of the exams. Some of the science teachers mentioned for example the need to review mathematics topics in their class in order for students to 'get to the science'. However they were often reluctant to spend time on these subjects, teaching only algorithmic, functional mathematics as they felt these topics should really be covered in the mathematics classroom. With the need to cover the examined science material in their classes, many felt that there was no time to teach mathematics concepts in science.

In this way the exams affected teaching style as well. Teaching in a procedural way, as opposed to teaching for understanding, was something that happened when exam time drew near for all topics in both science and mathematics classes. Anthony (science) described a change in his teaching approach and focus when exams were drawing nearer:

> I definitely teach it in the context of what the examiner is going to ask for, cause by the end of year eleven I'm playing the exams game. I'm almost, not teaching for understanding, I'm teaching, "look as soon as you see this question write down the wave equation. Right, now let's hope you can rearrange it. Now just show me how you would rearrange this?" yes they've got it, ok, good. That's how I'd approach it.

Many teachers also mentioned that maths was being taken out of the science curriculum. Both in the national curriculum and on the exams teachers saw a change from what they considered to be the more traditional science curriculum to one with a focus on science in society. In terms of the mathematics content, much more information was given to the students in the exams, and therefore they were required to do or know less. Anthony (science) commented about one of the exams, "This is higher level, yet they're given the blooming equation." Similarly teachers noted that in science questions involving graphs, the axes were given and labelled. In maths on

the other hand teachers noted that although there were many word questions, the context was often not integral to the problem and the units were given to the students for their answers.

Au (2007) reviewed qualitative studies on high-stakes testing in the United States and looked at their impact on subject matter content, the structure of curricular knowledge, and pedagogy. His findings reinforce what the mathematics and science teachers were experiencing; in one way or another, testing affected all three aspects of the curriculum. He found that content was particularly affected, as topics became limited to what was going to be tested. This finding was in line with the mathematics and science teachers who found that the focus in their classrooms had to be on topics that would be covered in the national tests (GCSEs and A-Levels).

National Curriculum

Alongside the exams the national curriculum also helped to create the division between mathematics and science. It was generally assumed that anything mathematical should be taught in the maths class, in order to be used as a tool in science, and when a mathematical concept arose in science first it was still seen as the responsibility of the mathematics department to teach for an understanding of the mathematics. A few areas specifically arose where science teachers were aware that they were teaching a mathematics concept before it was taught in the maths classes. Ivan (science) found that graphing was an issue that was not coordinated lower down in school:

> Ironically even our year 7s are required to be able to plot graphs and interpret the graphs, but unfortunately when we spoke to the mathematics teachers they said that they wouldn't need to learn about graphs until they're in year 9, so these are some of the cross-curricular issues that come up between mathematics and science.

Another curriculum issue brought up by Ivan (science) was to do with setting in maths and science. Because students in his science classes might be in different sets in mathematics, some students might have covered a particular mathematics topic before it occurred in science while others might not. Walter (science) also mentioned that students in A-Level biology often were not doing A-Level maths, and so while certain mathematical topics might be covered in the maths curriculum, students might not necessarily be in the maths class.

All of the maths teachers were surprised by certain aspects of the questions in the science textbook. Many of the science questions were at the same level or above that which would be expected for middle to lower sets in GCSE maths. The difficulty as determined by the teachers varied, but all of them found things that they thought would be difficult for their students to do because they were at a higher level than would be covered for their middle to low ability GCSE sets.

These disparities reinforced the algorithmic teaching style that was used to bolster performance on exams. In addition to other issues associated with teaching algorithms rather than teaching for understanding, Au (2007) found that teaching subjects as a series of procedures hindered the drawing of connections between topics and subjects, further reinforcing the separation between disciplines.

Problems with separation

The separation of disciplines stemming from the exams and the curriculum was consistent with difficulties students had with learning and making connections across

subjects. A number of factors seemed to play a part in ultimately making it difficult for students to apply the mathematics they learned in their mathematics classes to their science classes.

Interpreting and applying

One aspect that made the use of mathematics in science class difficult was a lack of understanding of the meaning of the maths the students came across. Teachers cited the compartmentalising of maths topics and rote teaching techniques that could make it difficult for students to apply their mathematics. For a given problem in science, teachers felt that students would have difficulty first with the interpretation of the problem, that is, finding out what the question was really asking for. Next, students had difficulty deciding the appropriate formula or technique to use to answer the question, especially if the question was not embedded in the teaching of one particular topic. Finally students also had difficulty even when given an equation to use with choosing the right quantities to substitute into the equations.

Some teachers saw these interpretations or applications as being a science skill rather than a maths skill. In problems involving substitution or graphing, teachers felt that most students would not have problems with the more straightforward plugging in of numbers or plotting or reading of data from graphs. However interpreting and selecting these numbers or data points was more difficult, and this often had to do with understanding the concepts behind the relationships in a given formula.

However maths teachers felt that this inability to interpret or apply was an issue in maths as well. With word problems or contextualised problems generally, as well as with problems where the specific area of maths they needed to use was not spelled out for them. 'Running' procedures was fine but choosing the appropriate procedure or the right numbers to plug in to a procedure was difficult. Grace (maths) commented, "but what they do find really difficult is yeah, working out what area of maths they need, 'what's the problem really asking us for?'"

Compartmentalising

Many teachers talked about the compartmentalising of ideas to particular topics, both in maths and science and between maths and science. They felt that the teaching of concepts as individual topics as opposed to having more continuity between topics created barriers for students and made it difficult for them to remember concepts from 'different' topics that had been covered earlier in their class or in other classes. Seth (science) explained:

> I think by and large, most of the maths that we would expect them to know, they have covered or they do cover in their maths lessons. But then it's bringing it into chemistry and using it in chemistry, and that transition isn't always smooth shall we say. … And so, they might not, necessarily, I think there's the tendency for them to see maths very much as maths. And they don't see it as much as being applied.

Ivan (science) found this in his science classes as well. He talked about the teaching of isolated maths in mathematics class. He claimed that concepts such as gradient were taught without a context, and so when graphing occurs in science the students do not look for applications or see the relevance of the techniques they learned in their mathematics classes. He explained:

> You know just moving across from the mathematics class to the science class, they just switch off from maths, and they do not expect to come and meet

> mathematics again. And that's one big problem. They do not understand the cross-curricular factor in their learning.

Further research

With the great importance teachers gave to the national exams, the next step of my research will be to look into how the science and mathematics exams compare, how they are or are not coordinated and why mathematics is being taken out of the science exams.

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