THE UNIVERSITY of York

Teaching approach and success in A-level Biology

Comparing student attainment in context-based, concept-based and mixed approaches to teaching A-level Biology

A review of literature on context-based approaches to learning biology and science

Martin Braund

Nuffield Foundation

Background

This review forms part of a research report funded by the Nuffield Foundation on student outcomes in Advanced level Biology in relation to the teaching approaches used. The full report will be made available to the Nuffield Foundation in due course.

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1.1. Scope of the review

The review of the literature is based on a systematic search of journals and databases and publications such as on websites, in policy and examination board documents, and from recent international conferences and seminars. The scope of the review is wider than sources only concerned with teaching biology in context as most research effort has been in other science disciplines, most notably in chemistry. Outcomes of most studies are considered relevant for all science subjects, including biology.

In the last decade there have been two large-scale systematic reviews of context-based science education. The first was carried out by researchers at York and was commissioned as part of a government sponsored initiative called the Evidence-Based Policy and Practice Initiative (EPPI) (Bennett, Hogarth and Lubben, 2003; Bennett, Lubben and Hogarth, 2007). This review had to use selection criteria set by the central review team and this limited selection of studies to large scale experimental designs using controlled (non-intervention) groups. The second review by Sadler (2009) covered a wider base of evidence of impact of context-based courses than the York study and was published in the review journal, *Studies in Science Education.* These publications formed a useful starting point for this review and a source of secondary studies to follow up.

Based on some knowledge in the field and the reviews mentioned above, seven journals were searched for relevant articles published between 1995 and 2011:

International Journal of Science Education
Science Education
Journal of Research in Science Teaching
Research in Science Education
Studies in Science Education
Journal of Biological Education
School Science Review

Two education databases, the British Education Index (BEI) and the Education Resource Information Centre (ERIC) were searched for relevant articles published in the same time frame as for the search of journals. Conference proceedings of the following prominent organisations in science education, published in the last ten years, were scrutinised by sight or searched by the selected keywords (see below), where this facility was available:

National Association for Research in Science Teaching (NARST)
European Science Education Research Association (ESERA)
International Organisation for Science and Technology Education (IOSTE)
South African Association for Research in Science, Mathematics and Technology Education (SAARMSTE)

Some sources, for example the MA thesis on SNAB (Salters Nuffield Advanced Biology) by Jenkins (2007), were included on personal recommendations of research team members or other professional contacts.

1.2. Search criteria – keywords

Sources, published in English between 1995 and 2011, were searched on the following keywords:

Context-based
Context-led
Impact
Science-Technology-Society (STS)
Authentic
Science
Biology

The keyword 'authentic' was included after reading the article by Shaffer and Resnick (1999) who identified four perspectives of authenticity; real-world authenticity, authentic assessment, personal authenticity, and disciplinary authenticity. It seemed the first and third of these perspectives might uncover relevant work but, as summarised by Yarden and Cavalho (2011), most studies are concerned with ways in which courses in schools try to model the activities and inquiries carried out by biologists-scientists so that they are a more realistic representation of 'real science'. Subsequently studies in the area of the 'authentic curriculum' were considered to be of peripheral interest as they deal with a more limited part of context-based teaching.

1.3. Structure of the review

The review is divided into sections covering: a rationale for context-based learning in science, definitions and examples of context-based learning, centres of activity in context-based approaches and evidence of impact of context-based science.

1.4. A rationale for context-based learning in science education

Several publications identify a main driver for development of context-based teaching in science as student disaffection and boredom with ways in which science is presented in traditional concept-led courses (Anderson, Holland and Palinscar, 1997; Bennett, Hogarth & Lubben, 2003, 2007; Cho, 2002; Gilbert, Bulte and Pilot, 2011; Hsu, van Eijck and Roth, 2010; Lock, 1998; Lubben, Bennett, Hogarth and Robinson, 2002; Parchmann *et al*., 2006; Parchmann and Luecken, 2010; Pilot and Bulte, 2006; Ramsden, 1997; Reiss, Millar and Osborne, 1999; Sadler, 2009). Though pupils' attitudes to school science seem far worse in physics and chemistry than in biology (Bennett, 2003; Osborne, Simon and Collins, 2003) this has not meant that efforts to contextualise biology teaching have been ignored and, of course, SNAB is an example of such actions.

Gilbert, Bulte and Pilot (2011, p. 890-891) list five problems in science education that can be addressed by following context-based approaches:

(1) Widespread curriculum overload with many isolated facts and concepts of varying significance included for students to be able to get a mental overview of the science or sciences being studied.
(2) The content of the curriculum is fragmented so that there is incoherence within and between the conceptualisations attained by students—a worthwhile 'mental map' is not achieved.
(3) Students often cannot transfer knowledge to situations other than the one in which it was learned.
(4) The knowledge taught is too often not relevant to students' everyday lives.
(5) Confusion about the reasons why science should be learned by students.

According to these authors, context-based courses avoid these problems by providing learning framed within a context which is expected to be relevant to the students. Students' involvement in the context(s) is expected to legitimise learning and attainment of formal science (p. 819). Duranti and Goodwin see context as a focal event for science learning having: a *setting,* temporal and spatial; a *behavioural environment* (of participants) that frame the discourse about and in it; a *language* through which participants communicate; broader *language of register* in science such that there is wider application to students' mental maps of knowledge. In other words there is prominent constructivist element in context-based courses (Duranti and Goodwin, 1992, p. 6-8).

Teaching science in a context requires departure from traditional teacher-driven learning to a style incorporating more learner-centred activity (Cho, 2002; Lubben, Bennett, Hogarth and Robinson, 2002). Parchmann and Luecken (2010) see this as challenging as, not only does teaching require a wider range of approaches, but also that content might be outside teachers' previous experiences in the subject domain. These demands prompted the progressive involvement of teachers arranged as regional school clusters in the design, research, implementation and professional learning that is the basis of the "*im-Kontext*" family of science courses in Germany (see later – 2.7).

Even though biology seems to have enjoyed a more positive reaction from school students than in physics or chemistry, there have been criticisms that Biology has become less interesting in the last 20 years, due partly to a reduction in opportunities for practical work involving living things and field work (Lock, 1998; Tranter, 2004). Reasons for the decline in these opportunities are suggested as including: increasing costs, teachers' misconceptions of what is allowed under health and safety rules and over-reliance on video and other ICT resources, such as PowerPoint, as alternatives for contact with living specimens in the laboratory and field. Lock (1998) reported a consensus from biology teachers, educators, inspectors and others attending meetings who concurred that advanced level biology was too reliant on textbook-dominated, language-heavy teaching with scant references to modern biology and too few opportunities for biology teachers to pursue topics of their own and their students' interests. The literature originating from those who designed and/or researched SNAB, shows how the course has addressed these issues (see for example, Dunkerton, 2007; Hall, Reiss, Rowell and Scott, 2003; Jenkins, 2007; Lewis, 2006; Lewis and Scott, 2006; Reiss, 2006; 2008). The use of contextualised 'science storylines' that address the most important issues and key ideas of science of interest to students and have longevity in terms of importance to society was suggested in the influential report, supported by Nuffield, 'Science Beyond 2000' (Nuffield, 1998; Reiss, Millar and Osborne, 1999).

Writing on the key difference between SNAB and previous examination specifications at A-Level, Reiss commented that:

> *"Specifications have traditionally been constructed from a scientist's viewpoint with the concepts being developed in a way that is seen to be sensible by a scientist. Typically this means that pre-eminence is given to scientific concepts (Hart 2002). But many students see things differently and want teachers to show them why the concepts are important. One possibility is to make the context—or storyline—the driving force."*
>
> Reiss, 2008, p.891.

1.5. Definitions and examples of context-based learning in science

In the York EPPI review, the research team used the following definition for context-based approaches:

> *Context-based approaches* are approaches adopted in science teaching where contexts and applications of science are used as the *starting point* for the development of scientific ideas. This contrasts with more traditional approaches that cover scientific ideas first, before looking at applications.
>
> (Bennett, Lubben and Hogarth, 2006. p.7)

In the US and some other countries the term Science-Technology-Society is broadly synonymous with a context-based approach and so the definition provided by Aikenhead (1996) is helpful:

> STS approaches [are] those that emphasise links between science, technology and society by means of emphasising one or more of the following: a technological artefact, process or expertise; the interactions between technology and society; a societal issue related to science or technology; social science content that sheds light on a societal issue related to science and

> technology; a philosophical, historical, or social issue within the scientific or technological community.
>
> (Aikenhead, 1994, p.52-53)

Examples of context-based approaches in science range in the type and duration of intervention, from individual enrichment tasks used in lessons through whole lessons or sequences of lessons to whole courses of a term or more. In the majority of cases, for this review, the studies are of whole courses of a year or more unless stated.

Gilbert (2006) identified four models for the design of context-based courses: (1) context as the direct application of concepts; (2) context as reciprocity between concepts and applications; (3) context as provided by personal mental activity; (4) context as the social circumstances. In model 2, which applies to most context-based courses researched and reported in this review, Gilbert, Bulte and Pilot (2011) describe this model as providing; "a situation … selected (by the teacher or course designer) as a vehicle through which key concepts can be taught. The assumption is that there is a cyclical relation between concepts and context throughout the teaching, that is after the concepts are taught, their application in the context is presented, and then a new aspect of the context is focused upon as a prelude to the teaching of new concepts" (Gilbert, Pilot and Bulte, 2011, p. 823). These authors clearly favour models 3 and 4 claiming that in models 1 and 2 contexts are merely 'decorative'. They see models 3 and 4 providing better examples of courses where contexts are deeply embedded in teaching and lead to more reflective learning within the context itself. However, the examples they review are in FE or job-training situations where models 3 and 4 are a more natural consequence of career-oriented learning, rather than in the broader based learning environments found in school science.

1.6. Centres of activity in development and research of context-based learning in science

The York EPPI review, in 2003, indentified four main loci of effort in context-based approaches leading to design, implementation and evaluation of whole courses:

(1) In the US, *ChemCom* (American Chemical Society [ACS], 1988) and the Iowa project, Scope, Sequence and Continuity (Yager and Weld, 1999).
(2) In the Netherlands, PLON: (The Physics Curriculum Development Project, 1988).
(3) In the UK, The Salters' suite of courses.
(4) In Israel, *STEMS* (Science, Technology Environment in Modern Society) (Tal *et al.,* 2001).

Since this review there have been important additions, particularly relevant to Biology: the *im-Kontext* (in–context) suite of courses, coordinated through the Leibnitz-Institute for Science Education (IPN) at the University of Kiel (see below) and *BIOMIND,* an intervention project in inquiry-based authentic learning in Israel.

The "im-Kontext" family

In response to criticisms of science in the German education system and following unfavourable results of TIMSS and PISA, the Leibnitz-Institute for Science Education (IPN) at the University of Kiel, in conjunction with various other universities in Germany, set up (from 2002 onwards) context-based courses for schools in each of the science disciplines, "*Biologie im Kontext*" (BiK), "*Chemie im Kontext*" (ChiK) and "*Physik im Kontext*" (PiKo). All three schemes are based on the idea of 'symbiotic implementation' (Eilks, Parchmann, Gräsel, & Ralle, 2004; Gräsel & Parchmann, 2004; Pilling, Holman, & Waddington, 2001) whereby courses are co-developed and researched from the start by teachers in regionally based clusters of schools working in conjunction with academics and teacher educators in education departments or pedagogical institutes of partner universities. *ChiK* was the first to be established (in 2002), funded by the German Federal Ministry of Education (BMBF) and participating states. The central goal of this project was to implement the ideas of context-based learning (e.g. along the lines of Salters Chemistry) into the school systems of the federal states and to gain further insight into conditions fostering and hindering implementation of school innovation (Parchmann et al, 2006, p.1043).

As with all *im-kontext* courses, *Biologie im-Kontext* is aligned with four areas of competency identified in Germany's national standards: subject knowledge, inquiry acquisition, subject-related communication and valuing and decision-making. PISA has had an influence on course design, as areas identified by the PISA team have been used as foundations for course content: life and health, Earth and environment, technology and genesis of knowledge (Prenzel *et al.*, 2004). As most *im–Kontext* group cluster projects included schools of so many different types and classes of widely varying ability and ages, research on impacts on student learning outcomes and attainment is very limited. The majority of research effort has been on the match of course design with theoretical models of aims and purposes of the science curriculum (Hamman, 2011) or on the operation of learning communities and impacts on professional learning of teachers (see: Elster, 2010a; 2010b).

Biomind

BIOMIND is a 12-month intervention comprising about 20% of a biology course for 16-18 year olds in Israel (Zion *et al*., 2004). It is based on the claim that, to be authentic, inquiry-based learning (IBL) ought to be as close as possible to the styles and processes of IBL as used by practising scientists. *Biomind* has an assessed component that allows for autonomous but supported IBL study (involving tutor feedback) of whole organism biology in the field and laboratory. The aim is to help students think like biologists where all the elements of research are included such as; searching for and reading relevant articles, planning, observation and initial experimentation, hypothesising, focussed experimentation/hypothesis testing and preparation of research reports. Research outcomes are limited to evaluation of course provision against aims and some non-quantitative evidence that students have improved 'concepts of evidence' as a result of following the course (Zion *et al*., 2004).

1.7. Evidence of impact of context-based approaches in science education

The majority of research studies have concentrated on the effects (impacts) of context-based learning approaches on students' attitudes (to science subjects and/or to studying science subjects in schools), students' abilities, skills or knowledge in the subject or more general educational outcomes such as critical thinking, argumentation or decision-taking. There have been a few studies of gains in professional learning of teachers or of change in teacher behaviours, task selection or variety in teaching, as a result of moving to using more context-based approaches.

1.7.1. Evidence of impact on students' concept learning

The majority of studies seem to show that concept learning outcomes from context-based courses are at least as good as from 'traditional' (concept-led) courses (Bennett, Lubben and Hogarth, 2007). There are a few examples of studies that show a marked impact in favour of context-based studies. In research associated with a science project in Iowa, students taking a context-based course showed significantly better understanding than those following traditional courses (effect size 1.52). Improvements were most notable for lower ability pupils and female students (Yager and Weld, 1999). In a rare RCT study by Tsai *et al.* (2000), students following an STS course showed less frequent misconceptions of key science ideas than those who had not experienced the course. In a more recent study in Colombia, Castano (2008) compared discussion outcomes of two groups of 4th graders (9-10 years old), one who had discussed STS issues and one that had not. Improved definitions for concepts in biology were noted for the STS group including of; ecosystem, biotic-physical interrelationships, food chains and impacts of alien species. In the *Biomind* project in Israel, Zion *et al.* (2009) claim that students following the course had improved concepts of evidence, though their evidence base for these claims is rather questionable. In another Israeli study, Dori, Tal and Tsaushu (2003) showed a very large effect (effect size 2.27) for gains in knowledge of concepts in biotechnology. In this study it was the very large gains for lowest ability groups that resulted in this effect size. The highest ability groups showed little or no shifts in their, already satisfactory, understanding.

There are studies showing an improved understanding of concepts closely associated with the teaching context of an STS intervention. For example Klosterman and Sadler (2010) showed students following an STS approach had improved concepts of global warming. A study by Khishfe and Lederman (2006) showed slightly less significant gains in the understanding of the same concepts (associated with global warming and climate change) but that students showed a much finer grained appreciation of the nature of science. Zohar and Nemet (2002) showed that STS enrichment lessons on genetic diseases and genetic counselling improved knowledge of basic genetic processes. However, gains in appreciation, knowledge and understanding of the nature of science, according to Sadler's review (Sadler, 2009, p. 25), remain elusive with little empirical evidence to support positive changes due to teaching in STS contexts.

Critiques of studies of impact on students' concept learning

There have been criticisms of research on the impact of context-based STS approaches on students' conceptual understanding. These centre mainly on the reliability of methods used to measure conceptual change for two different sets of experiences (e.g. through using different test-exam items) or on the too close match between criteria for course design or content and those for assessment (Barab and Plucker, 2002; Bennett, Lubben and Hogarth, 2007). The main problem has often been that students following concept-based approaches have (quite naturally and unproblematically in the eyes of some researchers) been tested using questions that value and draw on the approach they have been taught through while those following more conventional courses have been tested using questions more aligned with the other (conceptual) approach. The obvious outcome is that context-taught students do well on context-type questions and concept-taught students do well on concept-led questions. In a study by Winther and Volk (2004) the researchers claim that the differences in assessed outcomes in favour of students taught using STS approaches was underestimated because they were tested using conventional methods that favoured conceptual learning over contextualised learning. In this case the researchers seem to favour a methodological bias that could improve the size of the slight effect they reported! In the case of the Yager and Weld (Iowa) study, reported earlier, test items were designed by the researchers who were also engaged in course design and development. Thus course objectives that underpinned the teaching were aligned with the test items used to measure the effect of the course. This closeness between design and evaluation led Bennett, Lubben and Hogarth to wonder if, in the future, evaluation ought to be separated from course design and carried out independently by those who were not commissioned in course design and development (Bennett, Lubben and Hogarth, p. 367). However, it is worth pointing out that, where evaluators were also course a designer, no evidence of bias was found in studies considered the York EPPI review teams. In an early study of a Salters Chemistry course at GCSE level, Ramsden (1997) avoided bias in test design by selecting uniquely designed question items and adapting others from a bank of test items, independent from the taught course. Barab and Plucker (2002) used questions randomly selected from TIMMS and NAEP to avoid similar methodological criticisms. It is interesting to note that in both these studies (Barab and Plucker, 2002; Ramsden, 1997) no significant performance differences were noted between treatment and control groups. In Swaziland researchers explored student performances of groups following context and non-context teaching using both treatment related test items and the reversed styles of tests for each treatment group and found no significant differences in performance (Dlamini, 2003; Putsoa *et al*, 2003).

These latter studies are almost unique as few researchers seem to have used an equivalent testing situation to measure differences in concept knowledge and understanding that might be due to differences in teaching approaches. This is one of the reasons why the current study of teaching approaches and students' assessed outcomes (using examination results) being carried out at York, is important as it avoids the problems noted above by drawing on results from a common examination where all questions are taken by candidates irrespective of which teaching approach was followed.

1.7.2. Evidence of impact on students' attitudes, motivation and interest in science subjects and to science subject teaching

There is much stronger evidence of positive impact of context-based teaching of science on students' attitudes, interest and motivation than there is of shifts in student performance (Bennett, Hogarth and Lubben, 2003; Bennett, Lubben and Hogarth, 2007; Ottander and Eckborg, 2011; Parchmann and Luecken, 2010; Sadler. 2009). For example, in the York EPPI review only four of the 17 selected experimental studies of performance change showed definite improvement in conceptual understanding for students following context-based courses, while seven of the nine studies that explored students' attitudes showed positive impacts. Of these studies two, in particular (Smith and Mathews, 2000; Yager and Weld, 1999), show that girls in classes following STS approaches held more positive attitudes to studying science than their female peers in classes taught using conventional (concept-led) approaches.

Part of a rationale for teaching science in context (discussed in section 1) is that courses provide increased motivation for students to continue to study a science subject at a higher level or to enter a science-based career, because they have been (more) interested in the subject at school or college. Evidence from evaluation of *ChiK* in Germany indicates that this was true for students in many of the schools involved in the project (Parchmann, *et al*., 2006) as was the case in research on Salters chemistry courses (Barber, 2000; Ramsden, 1997).

Smaller scale interventions and enrichment actions of an SSI nature can improve student motivation and interest. For example, Albe (2008) analysed student discussions in lessons about risks of mobile phone use and claimed they improved motivation. Bulte, Westbroek, de Jong and Pilot (2006) showed that student motivation improved as lesson designs shifted from a content only focus towards lessons focussed more on contexts of local interest, such as about water supply quality. In a few studies there is evidence that students' improved attitudes or motivation might be more to do with a change in school routines than in the ways in which science content was taught. For example in a study by Harris and Ratcliffe (2005) of a 'collapsed day' arrangement in the UK, where the normal subject allocated timetable is suspended to allow for day-long studies integrating science with humanities subjects, the researchers found it difficult to distinguish between effects due to changes in teaching contexts from changes in the school timetable. Sadler (2009) comments that students in some *ChiK* project schools saw context-based lessons as just another science learning experience, different in that contexts featured more prominently, but generally consistent with the type of teaching previously experienced. Sadler comments that this contrasted with somewhat exaggerated positive expectations of teachers' views of how they thought pupils had perceived the course. In Jenkins' study of student attitudes to plant biology in SNAB and non-SNAB classes, it was found that SNAB made little difference but that students' realisation of the importance of studying plants had improved slightly for the SNAB group (Jenkins, 2007).

1.7.3. Evidence of impact on students' critical thinking and argumentation

Commensurate with a marked increase in research activity on argumentation and critical thinking in science education in the last ten years (see for example, Jimenez-Aleixandre and Erduran, 2008), there have been a number of studies that have explored whether teaching in context using STS approaches improves these qualities. Early studies exploring links between thinking analytically and experiencing lessons set in everyday contexts showed such links are supported (Gil-Perez, 1996; Perrone, 1998). More recently, Zeidler et al. (2009) studied 4 classes of 16-18 year old students enrolled in anatomy and physiology classes in treatment and control groups and found a significant increase in examples of reflective reasoning (measured on the RJM scale) for the treatment classes (effect size 0.76). These researchers concluded that familiarity and personal connectedness with the teaching contexts produced higher level argumentation and reasoning and a more sophisticated epistemological understanding. In Zohar and Nemet's study of SSI treatments in teaching genetics (Zohar and Nemet, 2002), researchers found that, although students in treatment groups showed an overall decrease in the numbers of conclusions stated, the mean number of justifications per conclusion and the numbers of ideas expressed in conversational turns increased significantly. Zohar and Nemet also showed that students showed an increase in the amount of biology content they brought into their arguments. Similar increases in justifications made and in the quality of argumentation have been noted for students engaged in STS activity (Albe, 2008; Tal and Kedmi, 2006).

Reiss analysed students' ethical reasoning in visit/issue reports submitted for the SNAB examinations on the basis of frameworks identified in teacher guidance: rights and duties, utilitarianism, autonomy and virtue ethics. His study found that utilitarian ethical reasoning was often based on examples consequential reasoning and was widely used. The remaining frameworks were used substantially less often. In addition he found that students mostly argued anthropocentrically though many of them also argued ecocentrically and/or biocentrically.

1.7.4. Evidence of impact on teaching

The main thrust of research on the *im-Kontext* suite of courses has been to explore shifts in teachers' perceptions of changes in their teaching, particularly towards more competence-based and student-oriented approaches that might be due to teaching science subjects in context (Elster, 2010a; 2010b; Parchmann and Luecken, 2010). As far as teachers' intentions to change are concerned, five criteria seem to have emerged that are most significant as predictors of change: collaboration, having a common goal, output orientation, reflection and continuous teacher learning (Parchmann and Luecken, 2010). In the physics course, *PiKo*, teaching changes away from traditional methods seemed to be linked with the extent to which teachers could see the benefits of students' more independent learning. In the *ChiK* projects, most change in teaching was in schools where school visits were part of the associated INSET (Parchmann and Luecken, 2010).

In her evaluation study of the SNAB pilot, Lewis used interview data to look at teachers' treatment of biological content, use of discussion, encouragement of 'active learning', approach to practical work, use of computer-based resources and selection of activities (Lewis, 2006; Lewis and Scott, 2006). She found that, at first, some teachers brought in more content than was required, for example about stages of meiosis in the topic on inherited diseases such as cystic fibrosis, when this was clearly not required. Reasons were to do with teachers' traditional established repertoires, wanting to give a more complete 'picture' of the biology or including what were thought be better or additionally interesting examples of the biology. Where teachers used discussion, it was about established knowledge rather than contested knowledge or ethical or social issues in biology. Where these second two types occurred, discussions proved problematic because whole class discussions lacked focus or teachers felt unpractised in the pedagogical approaches required to run productive discussions. Lewis also found teachers had varied views on what constitutes active independent learning and how to facilitate or manage it. One or two felt uncomfortable with this aspect. Teachers' abilities to adopt more open-ended investigative practical work depended on the extent to which they were prepared to subscribe to this approach in the first place – as a condition of their epistemological-pedagogical viewpoints. Teachers were unused to self-autonomy in selecting learning tasks and so tried to do everything – as the pilot proceeded they became far more selective often on the basis of sound educational outcomes.

Dunkerton analysed students' visit/issue reports over the SNAB pilot and found that improvements were in descriptive rather than analytical components (Dunkerton, 2007). Many students found it difficult to write full evaluations or discussions of their visits, linking with Lewis' findings that SNAB teachers found classroom discussion requirements difficult and in particularly encouraging students to adopt a more critical approach to handling information.

1.8. Summary and concluding remarks

In the last ten years there has been diversification of research on impact of context-based science teaching. Firstly there has been an extension to the location of studies, reflecting increasing interest in countries outside the loci of effort identified in the York EPPI review, for example in Korea (Lee and Erdogan, 2007), Colombia (Castano, 2008), Germany (Parchmann and Luecken, 2010), Sweden (Ottander and Eckborg, 2011) and Portugal (Santos and Braund, 2009). Secondly there has been a widening of the areas of impact studied from those mainly looking at effects in terms of student performance and attitudes to encompass studies on development of students' discussion and argumentation and the extent of change in teaching repertoires of those involved in teaching context-based and STS approaches. To a certain extent this has reflected broader trends in education research but it also marks a continuing and strengthening research effort in the field.

The consensus on the strength of evidence on impact of context-based and STS approaches is that there is good evidence that students' knowledge and understanding is not less than students who have followed conventional concept-led approaches. There is strong evidence that students' interest in science, their motivation in the subject and the possibility that they might continue studying science subjects are improved by having followed context-based or STS approaches, particularly when exposed to longer duration enrichments, interventions and whole courses. There is some evidence that teachers change their teaching behaviours to encompass more student-centred activity but that they might be more reticent about using discussion and argumentation particularly when these address controversial or ethical issues. As a consequence, although there is evidence to show that some students improve their skills in critical thinking and argumentation as a result of context-based teaching, there is probably some way to go in getting the most from classroom discussion. The intentions of those who designed and developed context-based courses, that teachers will change to using more student-centred teaching and active learning, may be a rather distant goal. There is evidence that teachers trying to teach in context may adopt a 'business as usual' approach where, although the contexts of science are visible to the students, teaching styles have hardly changed.

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