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## *Chapter 1*

# **DEVELOPING A RESEARCH PROGRAMME IN SCIENCE EDUCATION FOR GIFTED LEARNERS**

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## **ABSTRACT**

An urgent issue in science education is better meeting the needs of those learners who are working at levels of attainment well above those of their peers. Variously known as the gifted, talented, or highly able, these learners are not sufficiently challenged by mainstream science provision, and so may lose enthusiasm and engagement from science. This is not only an issue for the students themselves, but also for the global community that faces environmental, medical and other challenges that will rely upon advances in science. Whilst there has been a considerable amount of work on offering science enrichment provision in many countries, the nature of science education needed for the gifted has not been a main focus on research within the field. The chapter sets out the basis of a research programme to respond to this deficiency. The key concepts and issues are discussed, and 'hard core commitments' of such a programme are proposed. The characterisation of the research programme allows the proposal of an outline 'positive heuristic' for the programme setting out the key directions for future research.

## **INTRODUCTION**

Whilst 'gifted education' has certainly been an area of considerable activity for some decades (Dai, Swanson, & Cheng, 2011; Ziegler & Raul, 2000), there has been much less attention to the particular needs of gifted learners within the science education research community than would seem to have been merited. Yet there are strong reasons to consider this an area that should be made a priority within the field (Taber, 2007b). This chapter sets out the rationale for encouraging research in this area, and offers - if not a manifesto, then at least - a sketch of a research programme (Lakatos, 1970) into science education for the gifted.

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It is important to acknowledge that there is no clear consensus on just which learners should be considered as gifted in science, and this is clearly one issue that can impede research. Moreover, some working in education would reject the notion of giftedness as useful either on empirical grounds (it is difficult to unambiguously identify gifted and non-gifted learners) or principled grounds (that the whole notion of some, but not all, people being 'gifted' is unacceptable). Despite this, teachers in many national contexts are expected to provide for gifted learners (as defined and identified in their local contexts), and regardless of acceptance or rejection of *the label* there are good reasons for considering there to be a major issue within science education regarding the differentiation of educational provision for those learners that variously might be recognised as precocious, advanced, highly achieving, of high potential or aptitude in science, etc. (Department for Education and Skills, 2002; Riley, Bevan-Brown, Bicknell, Carroll-Lind, & Kearney, 2004; The National Strategies, 2008).

These points will be picked up later in the chapter, but the general issue is that *any learner will only make good progress in a subject if learning opportunities are matched to their current state of readiness*. This can be seen by considering extreme cases. Consider two learners, both of whom are motivated to learn, and have good study habits: (i) a middle school student being introduced to the general principle that matter is quantised (that apparently continuous matter can be understood to be made up of tiny, somewhat discrete, entities such as molecules and ions), and that the bulk properties of materials rely on their particular structures at a submicroscopic scale; and (ii) a doctoral student undertaking research into the electronic structure of organic conductors at a molecular scale. As a kind of gedankenexperiment we might imagine that these two learners are swapped (perhaps by inquisitive alien educational researchers, or more likely due to some administrative error in an information management system) and consider the learning about molecular structure that would take place.

It seems pretty obvious that the middle school child would not have the background knowledge and understanding to make any headway with the PhD project (Ausubel, 2000). This need not imply the same student does not have potential to one day undertake a PhD in this area (they might), but they are certainly not ready for this yet. Bruner (1960) famously talked of how any learner could be taught any topic in some 'intellectually honest' form - the middle school's curriculum is designed to offer such an intellectually honest simplification of the topic for students at *that* stage in their learning and should offer the 'optimal level of simplification' (Taber, 2000): simplified enough to be meaningful to learners, yet honest enough to the subject matter to support further effective progression in learning. By contrast, the hypothetical PhD project would be set up to reflect an enquiry challenge, at the forefront of knowledge, for someone who has already successfully completed significant advanced learning about the topic.

Similarly the research student is unlikely to develop her understanding of her topic from attending the middle school class, no matter how well informed and skilled the class teacher might be. The doctoral student is certainly well equipped to *understand* the lesson - but the middle school class curriculum does not provide opportunities for further learning about the topic as the content is familiar and the level of treatment well below that level at which the student is working in her thesis project.

These imaginary students are displaced, rather than being natural classmates, and so our gedankenexperiment offers extreme cases, and real classes of students would not normally include such a wide spread of learners. None-the-less, every class - even in a selective

education system - is a group of individuals: each with unique background knowledge, different strengths and weaknesses; different interests and aspirations and so forth. In just about any real class *some* of the students will have mastered material others would struggle with; will know things that others were ignorant of; will be skilled in areas others lack skill in; and will hold idiosyncratic alternative conceptions not shared by their peers (Taber, 2014d). If we accept that optimal instruction is based on a match between teaching and the students' current state of learning (Taber, 2011), then differentiation is an issue in every classroom.

On many (if not all) matters that might be educational objectives in our classes - understanding photosynthesis; planning a fair test; using calibrated glassware - there is likely to be a spread of proficiency, and in many cases this is likely to approximate the familiar bell-curve shape of the Gaussian (normal) distribution. In such a distribution, most people score quite near the mean, whilst a few outliers may have scores considerably lower or higher than that mean. For those at the extremes a lesson pitched at the mean will often be problematic. For those most unprepared to work at that level (akin to our imaginary middle school student transported to doctoral studies) there will be little chance of achieving in class without considerable additional support. For those already performing very highly on the relevant indicators (akin to our imaginary research student placed in a middle school classroom), the material met in class is likely to be well-known and the tasks set too easy, and there will be little challenge. This can lead to boredom (Diezmann & Watters, 1997; Gallagher, Harradine, & Coleman, 1997), disengagement with the subject, and - at the very least - a lost opportunity to develop personal understanding and learn anything substantially new.

This is true, and should not be tolerated, in any educational sphere. In science education there is a risk that the most able learners fail to find sufficient challenge in science and look for intellectual satisfaction elsewhere - perhaps in the humanities and social sciences which by their nature more easily offer potential for differentiation because the subject matter (at least as met in schooling) more readily opens itself to students finding potential areas for extending themselves than is usually the case in traditional science courses. This is a generalisation of course, and does not acknowledge the skills of the teachers concerned. It is certainly not *necessarily* the case in science: enquiry work is one area where (when done well) there is considerable scope for learners to show individual flair and imagination (Taber & Cole, 2010; West, 2007); and teaching about the nature of science offers scope for the kinds of open ended intellectual engagement that gifted learners often find in subjects such as history and social studies (Taber, 2007c). Studying socioscientific issues (Sadler, 2011) may be challenging for many learners who excel in science (Levinson, 2007). Indeed, adopting a more 'history-and-philosophy-of-science-informed' approach to teaching about science (e.g. emphasising the nature and role of models and theories rather than letting students see science as factual) could offer both a more authentic reflection of science itself, and make the subject more appealing to many learners (Taber, 2007a).

It is clear that in many national contexts a good many learners become disenchanted with science in the secondary years, and whilst it is healthy that not all students have the same favourite subjects and aspire to the same career, it is commonly suggested that too many of those students with real ability and potential in science are choosing *not* to study science in advanced courses; *not* to major in science; *not* to seek to become scientific researchers; and *not* to look to work in a scientific career. Yet having a strong flow of capable and enthusiastic young people, and indeed a share of those with exceptional potential, is not a luxury in a

world beset by problems that science and technology can address. There are certainly some important issues where science and technology can make a major difference to our lives:

- Major outbreaks of fatal infections that medical science cannot yet readily cure;
- Regular food shortages in some parts of the world;
- Loss of natural habitat and biodiversity;
- Pollution from modern industry and consumer habits;
- Reliance on non-renewable, and highly polluting, power sources;

And so forth...

Science has potential to help tackle disease, provide 'greener' manufacturing, offer new fabrics which are better wearing and more comfortable and even able to adapt to different environmental conditions, provide new digital technologies, clean up pollution, develop new crops with disease and drought resistance, etc. Science will continue to do these things - but is likely to make better progress if a fair proportion of students with the 'brightest minds' opt to work in scientific areas. If *too many* of those learners that we might judge gifted in science find other areas - such as perhaps business and finance, or media, or advertising - to be more attractive and satisfying than science then progress on major issues effecting millions of lives (and perhaps ultimately human survival) will be slower.

So whilst there are certainly some challenging and even sensitive issues regarding how to best understand giftedness in science, there is also a very real concern that science educators in many national contexts need to do more to make sure that science learning is intellectually challenging and satisfying for the most able learners. The purpose of this chapter is to offer an outline of a research programme that could act as an organising schema for this area of research across educational phases and national contexts. First however, the notion of research programmes is explained.

## SCIENCE EDUCATION AS A FIELD OR FIELDS

Science education is now widely recognised as a substantive research field (Fensham, 2004), or possibly even set of fields (Gilbert, 1995), and is mature enough to have developed a suite of prestige journals and a range of high profile associations. Moreover, science education is an active international field with traditions of work across different continents (Taber, 2012a). The increasing maturity of science education as a field is reflected in two major handbooks now being in their second editions (Fraser, Tobin, & MacRobbie, 2012; Lederman & Abell, 2014).

The nature of science education itself as an area of scholarship is less straightforward. In particular the disciplinary background of people working in the field is diverse: with some workers trained as natural scientists who have moved into pedagogic research; some who have moved from professional careers as school teachers before becoming research active (and many but not all of these will be science graduates); and others who have backgrounds in those disciplines on which education is founded (e.g. psychology, sociology), but who have developed lines of research within the context of science education whilst retaining a professional identify as a psychologist or as a sociologist etc.

By its nature science education is not part of natural science, although many of those active in science education research - and particularly in discipline-specific subfields, such as chemistry education research (Taber, 2013b) - are based in university science departments. Education is more of an applied social science, and when selecting methodologies appropriate for answering educational questions researchers usually need to adopt approaches developed in the social sciences rather than the natural sciences (Taber, 2014b).

However there are different understandings of what is meant by 'science', and whilst education is not a natural science, and indeed sometimes encompasses arts and humanities based research methods as well as social science approaches, it is still possible that research in education can be considered to be *scientific* (National Research Council Committee on Scientific Principles for Educational Research, 2002).

## RESEARCH PROGRAMMES IN SCIENCE EDUCATION

The question of the demarcation of science from other forms of activity has been discussed by a number of philosophers of science (e.g. Lakatos, 1974/1981; Popper, 1934/1959, 1974/1992). One particularly useful description of scientific activity was developed by Imre Lakatos (1970), who described the nature of *scientific research programmes*. For Lakatos a research programme had particular features that gave it its 'programmatically' (rather than serendipitous) nature, and which allowed it to be evaluated to determine whether or not it was 'progressive'. Adherence to a research programme that was not progressive, rather than seeking or developing a more promising alternative, was not scientific - and this was used as a criterion for claims that such programmes as Marx's notion of history or Freud's psychoanalytical programme fell short of being scientific (i.e. progressive).

Lakatos's model of science addressed some of the problems of a naive conception of science as able to produce absolute knowledge that is verified by empirical enquiry. Whilst the very essence of science is to be guided by empirical evidence, it is widely accepted that this is not unproblematic. For one thing, theories are generally underdetermined by data (Riggs, 1992). That is, no matter how well the empirical evidence fits one theory, it is quite possible to conceive of alternative theories that would offer just as good a fit. As a visual analogy - consider a line graph based on a finite number of data points. There may be an obvious line of best fit, but there are always other more complex functions that would also fit the data. The scientific equivalent of picking the best-fit curve relies on adopting values that are to some extent at least metaphysical. For example, William of Ockham's principle (known sometimes as Ockham's or Occam's razor) that the most straightforward explanation with the least auxiliary features is to be preferred is commonly used. This seems a sensible heuristic - but it cannot assure the right choice. It seems more likely that our imaginary swapped students find themselves in the wrong place due to an administrative error than because of alien intervention - but occasionally what seems unlikely may turn out to actually be the case.

Another problem in science is that very few scientific experiments can be considered to be a test of simply the hypothesis being investigated. Most such experiments are based on propositions that are logically of the form 'if...and if...and if...and if...and if...then...'. The 'and ifs' can refer to assumptions from existing theory that is widely accepted ('hard core')

commitments within a particular scientific tradition) or understanding of the instrumentation (often very complex in modern science). As we have seen above, a positive result underdetermines any particular conclusions, and largely under the influence of Popper (1934/1959) science is often now often described as hypothetical-deductive, working on a principle of producing conjectures and refutations (Popper, 1989). In Popper's model science proceeds by excluding hypotheses that are demonstrated false: i.e., falsificationism. Yet an experiment cannot lead to the absolute rejection of a discrete conjecture - only to a rejection of the conjunction of 'if...and if...and if...and if...and if'. These 'and if's may include things such as 'if the sample was of high purity and not contaminated' and 'if the power supply remained within close parameters' and 'if the technician added just the right amount of reagent' and 'if the observer accurately counted the damaged cells in the field of view' and 'if we selected an area of the habitat that was typical of an animal's range' and so on.

Lakatos recognised that despite the popular accounts sometimes met in school books, no single experiment can ever really be considered critical, and that scientists will often happily quarantine anomalies (results they were not expecting and which cannot - yet - be explained from within the theoretical framework adopted), that according to a simple epistemology should 'refute' their theory or model, and carry on regardless. Despite this appearing to be illogical from a simplistic falsificationist perspective, Lakatos recognised it made sense in a situation where any individual result should never be taken as an absolute basis for supporting or undermining a particular theory. Rather it is rational to put aside ('quarantine') anomalies for the moment, as long as the overall research programme can still be considered to be progressive, i.e. is still making progress. Clearly evaluating research programmes requires more expansive judgements (Lakatos, 1970): i.e., is theory still being developed (beyond *ad hoc* patching-up of failures to match results) and still suggesting fruitful avenues of empirical investigation?

Arguably, science education is a scientific field *to the extent* that those working in the field are adopting progressive research programmes. One area of work that has been identified as a research programme in science education (Gilbert & Swift, 1985) was based upon Piaget's (1970/1972) genetic epistemology and looked to inform curriculum and teaching using Piaget's notion of children's development occurring in stages that afforded different cognitive abilities (Bliss, 1993). This programme has supported extensive work on developing teaching aimed at 'accelerating' cognitive development by offering learners the contexts for moving on to the stage of (what Piaget referred to as) 'formal' operations needed to appreciate the abstract nature of scientific concepts and theories (Adey, 1999).

An alternative perspective that has been widely recognised as a major tradition in science education, a paradigm or research programme (Driver & Easley, 1978; Gilbert & Swift, 1985; Solomon, 1993; Taber, 2006, 2009b), has been based in constructivist ideas on how learners come to knowledge and how this should inform teaching. This constructivist programme drew upon general features of Piaget's work, but considered how learning occurs in particular concept areas drawing upon the resources available to a learner - such as prior learning (Taber, 2014c) - rather than accepting that the learner operates with domain-independent general levels of cognition. This area of work included a vast research effort to explore the nature of learners' thinking prior to being taught science topics (Duit, 2009), and has led to the reporting of many 'misconceptions', 'alternative conceptions', 'intuitive theories', 'alternative conceptual frameworks' and the like.

Indeed this area of work become so expansive that it faced some criticisms for unduly dominating the field (Solomon, 1994), to the extent that at one point it seemed to be by far the most visible area of activity in science education research. This is no longer the case, and for example in recent years there has been the development of an alternative research programme which is based upon cultural-historical and socio-cultural theory (Smardon, 2009), and which is increasingly important in science education (Fraser et al., 2012; Taber, 2014a). The physicist and historian/philosopher of science Thomas Kuhn (1996) understood alternative paradigms operating in a field to be in competition, and from that perspective the shift in interest among researchers from the constructivist programme to the sociocultural programme (like that from the Piagetian to the constructivist programmes) could be seen as a kind of paradigm shift. However, in Lakatos' model several different alternative research programmes may continue to be progressive in a field. Given the complexity of factors influencing learning, it seems sensible that a field such as science education can support complementary research programmes with different foci - although one might consider the ideal that these would at some point in the future find ways to coalesce into a single programme.

Indeed one conceptualisation of the constructivist research programme as concerned with the contingent nature of learning in science would admit general features of the Piagetian programme (without treating domain-independent stages as an absolute) and aspects of sociocultural perspectives - seeing any distinction between 'personal constructivism' and 'social constructivism' as a choice of focus for particular studies rather than incommensurable conceptual frameworks (Taber, 2009b).

## **THE FEATURES OF RESEARCH PROGRAMMES**

Lakatos (1970) considered that research programmes could be characterised as having key features, including what he referred to as a hard core, a protective belt, and heuristics to guide research. The hard core was central to the identity of the programme. From his study of historical cases, Lakatos considered that a scientific research programme forms around a set of specific assumptions that are established at the outset, and which act as the (intellectual) starting points for the programme.

A research programme's hard core comprises a set of intellectual commitments that are so central to the programme that they are unquestioned within the programme. A naive notion of science would suggest that everything should remain open to questioning: in Lakatos's model the rejection of a hard core assumption is certainly possible, but in effect means the abandonment of that particular research programme. As an example from science, we might consider a Lamarkian research programme to assume that acquired characteristics can be inherited, and a decision to reject that premise (e.g. to adopt a Darwinian model) means a rejection of the Lamarkian programme.

Piaget's research programme (1970/1972) has as part of its hard core that all children progress through the same series of basic stages of cognitive development, in the same specific order, and that this explains important domain-independent aspects of a child's intellectual performance. Someone working in that programme who came to the view that this basic premise was inconsistent with the empirical evidence would need need to abandon the

programme. In such cases it is perfectly possible for a researcher to join (or develop) a new programme that inherits some of the commitments of the abandoned programme (Taber, 2009b), but substantive change in the hard core assumptions implies the development of a new programme.

Lakatos suggested however that those working within, and committed to, a research programme did not readily question hard core assumptions: as normally these were insulated by the 'protective belt' of theory that is developed around the core, and which could be considered to offer 'refutable variants' consistent with the commitments in that hard core. Moreover, unlike in a naive falsificationist notion of science (where data that appear to be evidence against a hypotheses should lead to its rejection), Lakatos (1970) suggested that in real scientific research programmes scientists would be prepared to quarantine inconvenient results - not to deny them, but to recognise them as potential problems for the programme that should be considered as puzzles that *in time* need to be addressed. A programme that accumulated increasing numbers of such quarantined anomalies that were *not* being tackled would be an indication of a programme that was no longer 'progressive' (but rather was 'degenerative'), and so less worthy of scientists' investment of resources.

### **A PROGRESSIVE RESEARCH PROGRAMME FROM SCIENCE EDUCATION**

As an example, an analysis of seminal studies from the constructivist tradition in science education (Driver & Easley, 1978; Driver & Erickson, 1983; Gilbert, Osborne, & Fensham, 1982; Gilbert & Watts, 1983; Osborne & Wittrock, 1983), suggested a research programme existed based around a series of key commitments that had been adopted by researchers. These were (but not necessarily in the phrasing of the original authors):

- Learning science is an active process of constructing personal knowledge
- Learners come to science learning with existing ideas about many natural phenomena
- The learner's existing ideas have consequences for the learning of science
- It is possible to teach science more effectively if account is taken of the learner's existing ideas
- Knowledge is represented in the brain as a conceptual structure
- Learners' conceptual structures exhibit both commonalities and idiosyncratic features
- It is possible to meaningfully model learners' conceptual structures (Taber, 2009b, p. 124).

The constructivist programme has been so influential (and arguably successful) that few people working in science education today would doubt most of these premises - even if they might quibble over the precise wording. One potential criticism of this characterisation here is that it seems to have a strong focus on the individual learner ('personal constructivism') - however, social aspects of teaching and learning are not excluded and indeed the reference to teaching science acknowledges that learning usually takes place in a social (e.g. classroom) context. However, some scholars go beyond stressing the role of social and cultural factors in learning to suggest that knowledge should be seen as distributed across a community (Collins,



2010) rather than located within individual minds - and someone with that commitment could not be considered to be working within a research programme having hard core personal constructivist premises (such as 'knowledge is represented in the brain as a conceptual structure').

The heuristics of a research programme set out directions for developing the programme. Any one of the premises above suggests empirical questions (what are the mechanisms of personal knowledge construction? what factors influence these processes? etc.) and those that seem to offer promising lines of work form a positive heuristic. Indeed, an analysis of this area of work suggests that each of the hard core assumptions above suggests lines of enquiry which researchers have indeed adopted - making (to date) various degrees of progress (Taber, 2009b). During this work a wide range of theoretical ideas have been developed around the hard core (making up the programme's protective belt).

What Lakatos (1970) called the negative heuristic refers to the taken-for-grantedness (within a programme) of not setting out to test the premises. So, for example, someone working within a research programme developed from Einstein's theory of special relativity would not undertake research to measure how the speed of light varies with an observer's state of motion - as the invariance of the speed of light is a hard core commitment of the programme. A researcher working in the constructivist programme discussed above would not set out to develop a general model representing how all 14 year olds studying in the English education system conceptualise energy - as such a general model is inconsistent with the assumption that each learner has a somewhat unique conceptual structure (i.e. 'learners' conceptual structures exhibit both commonalities and idiosyncratic features'). A researcher *might well* develop a model which represented *the commonalities* of a class of learners in relation to a particular concept area (e.g., Taber, 1998), as the programme includes a commitment to such commonalities: but the notion that a detailed model of a conceptual structure would accurately represent the conceptual structures of each member of a general class of learners is excluded by the hard core of the programme.

The other key aspect of Lakatos's model of research programmes is what he termed the 'protective belt' of auxiliary theory that develops around a programme's hard core. Under the positive heuristic the programme develops a body of theory that is consistent with the hard core commitments. However, as suggested above, any theory is underdetermined by available evidence, and different alternative auxiliary theories may be consistent with any particular hard core. For this reason, such theories are described as refutable variants, as they are open to being rejected and replaced in the light of new evidence. The term protective belt suggests that these theories act to protect the hard core because whenever empirical evidence seems to be inconsistent with the current state of the programme's theoretical apparatus it is possible to adjust the apparatus by modifying the protective belt and leaving the hard core untouched. (That is the '...if...' of a conjunction of 'if...and if...and if...and if...and if' is protected because one of the '...and if...' clauses is sacrificed instead.)

This suggests of course that any set of hard core assumptions can be retained by sufficient adaption of auxiliary theory: and this reflects the conservative nature of much human thinking (Nickerson, 1998). Lakatos was aware of this, and he was not advocating a science that lacked the scepticism usually considered essential to scientific progress. This is why he suggested criteria for distinguishing a progressive (and so scientific) programme where over time the body of theory comes to offer a more coherent explanation for an

increasing evidence base from a degenerating programme where preferred commitments are increasingly supported by *ad hoc* and arbitrary patching-up of theory to 'save phenomena'.

The constructivist research programme has seen a wide range of theoretical developments which have motivated and been developed through empirical investigations (Taber, 2009b). As one example: early work on students' ideas in science suggested that 'alternative conceptions' were very tenacious and so difficult to address in teaching. This idea was criticised by those who considered learners' ideas to be in flux, highly contextualised and general labile (e.g. Claxton, 1993). Further research suggested that both views were too simplistic, and that learners' ideas vary considerably in terms of level of commitment, extent of (i) range of application, and (ii) integration within a wider network of ideas (Taber, 2009b). We also now understand much more about the different origins of learners' informal ideas and why they should vary in these ways (Taber, 2014d).

## **A RESEARCH PROGRAMME IN SCIENCE EDUCATION FOR GIFTED LEARNERS**

The remainder of this chapter will consider the current state of knowledge and understanding about gifted education in science and suggest how this area of work in science education might be developed through an agenda for research conceptualised through a scientific research programme.

### **POSSIBLE HARD CORE ASSUMPTIONS OF A RESEARCH PROGRAMME EXPLORING GIFTEDNESS IN SCIENCE**

It is possible to suggest candidates for the hard core commitments of a research program in science education for gifted learners. For example, the following may be suggested as ontological commitments that underpin this area of work:

- 1) A student's potential to benefit from teaching depends upon their current characteristics as a learner.
- 2) Learning depends upon learning opportunities being matched to a student's characteristics.
- 3) Learners show a wide range of current capabilities within any particular curriculum area, and vary considerably in terms of their potential for development with suitable support.
- 4) At any age or grade level there will be some students who are considerably further advanced in their science learning than their peers. [These students may sometimes be referred to as gifted in science.]
- 5) Science (and science subjects) present a broad range of learning challenges such that many students will have an uneven profile of current knowledge, understanding and skills.

- 6) Science provision needs to offer suitable learning opportunities to allow students to make progress in their learning. (Therefore: science provision needs to offer suitable learning opportunities to allow 'gifted' students to make progress in their learning.)
- 7) Particular science provision is indicated for those learners in any cohort who are too advanced to find substantive learning opportunities in the standard provision.

These commitments are consistent with the approach taken above in the introductory sections of this chapter. This characterisation of the background to a research programme is not exclusively about giftedness - what becomes clear when the theme is analysed in this way is that most of the underlying notions necessary to develop a scientific research programme into giftedness in science are shared with more general thinking about science teaching and indeed teaching in general.

The purpose of setting out the hard core in this way is both to make explicit what are considered to be essential shared commitments (i.e. does anyone looking to research giftedness in science education actually disagree with any of these points?), but perhaps more importantly to act as a starting point for identifying the questions that are suggested by these assumptions. Such questions, where robust answers are not already available, indicate directions - lines of work - for the research programme (the 'positive heuristic').

### **IS THERE A NEGATIVE HEURISTIC FOR THIS RESEARCH PROGRAMME?**

According to Lakatos' (1970, p. 135) model ('method') of scientific research programmes, such programmes have a negative heuristic that "specifies the 'hard core' of the programme which is 'irrefutable' by the methodological decision of the protagonists". In other words, someone who is working within the programme accepts (for example, in the mooted programme) that "at any age or grade level there will be some students who are considerably further advanced in their science learning than their peers" and would not develop a line of work that was based upon an assumption that all students of a particular age are currently capable of understanding or mastering the same set of concepts.

As the hard core represents strong ontological commitments there is a sense in which it tends to become taken-for-granted by those working in the field. So in practice the negative heuristic need not be a clearly specified set of rules, but can simply operate implicitly in guiding how researchers work. Yet in this particular area of activity, there is arguably a good reason to be explicit about the hard core of the programme. The list of candidate commitments for a hard core above does not seem especially radical, and it seems likely that few working in science education - or indeed with any experience of teaching in any academic area - would strongly disagree with any of these points. Yet a great deal of educational practice seems to be predicated on a very different set of (if often implicit) assumptions - that it is appropriate to set standard curriculum for particular grade levels, and to ask teachers to teach heterogeneous, and sometimes widely heterogeneous, groups of students following a common syllabus or scheme-or-work. In part this represents traditional practices that have themselves become taken for granted, and in part this recognises the economic

realities of public education (i.e. the need for teaching in classes of a size that reflects the teaching staff resources available).

Certainly at school level it is most common to organise classes by age-related grade - that is where the criterion for being in a grade usually relates to birth date rather than prior attainment. This is certainly administratively neater when legal requirements set out the ages of compulsory schooling. Attempts to move away from this system to see grade level in terms of prior academic achievement may be complicated when students have an uneven profile of achievements across curriculum areas, or where precocious intellectual ability is not matched by physical and emotional development: making the learner placed in a class of mainly older children feel out of place socially - or even isolated. Where a largely age related system is modulated by limited advancing of students to higher grades or holding back those not considered to be making progress there is the potential for considerable risk to student self-esteem and self-image when they are kept back with younger pupils (Martin, 2011).

Teaching uses three sets of tools in response to this situation. One is ability grouping - setting, banding etc. within grade levels (where there are enough pupils of the same age group within an institutional cohort to make this possible). The second is differentiation (Stepanek, 1999) - finding ways to differentiate within a class by modifying tasks, or setting tasks at which different levels of achievement are possible. The third tool is enrichment through activities that supplement standard curriculum fare. Each of these approaches has advantages and limitations - and practitioners would benefit from a stronger research base exploring the most appropriate forms of provision for gifted learners in science classes in various contexts and situations (e.g. institutional and curriculum contexts, disciplinary contexts, age/grade levels, etc.)

## **A POSITIVE HEURISTIC FOR THE RESEARCH PROGRAMME**

The characterisation of the hard core of a research programme should indicate directions for potentially fruitful research. It is possible to look at the suggested hard core commitments above and consider how they suggest questions such a research programme should seek to answer.

### **A Student's Potential to Benefit from Teaching Depends upon Their Current Characteristics as a Learner**

This assumption is widely accepted in education. When considered as a commitment within a research programme this principle raises issues of *how to best characterise learners to identify their potential to benefit from further teaching*. There is a great deal of material available to teachers on how to identify gifted learners - but much of this appears to link to 'craft knowledge' rather than be based upon sound research. A very common indicator used to define gifted learners is intelligence as measured through IQ tests, but there is a wide literature suggesting this is a much too limited approach (Charlton, 2009; Gilbert & Newberry, 2007; Gould, 1992; Sternberg, 2010). Teachers may instead use classroom experience to simply identify which students complete work quickly and at a high level with

little apparent effort. There are also common checklists that offer suggestions of gifted behaviours, such that being considered to demonstrate a selection of the listed behaviours is taken to indicate giftedness (Riley et al., 2004). Such lists usually contain what seem sensible potential indicators, but the origin, definition, and criteria for meeting, the indicators are often something of a mystery.

This all suggests that whilst the general principle (i.e., that a student's potential to benefit from teaching depends upon their current characteristics as a learner) is widely accepted, there is limited robust (i.e. systematically tested) knowledge about how to best characterise learners to predict their potential for further learning - and so there is much room for developing more evidence-based practice in this area.

One very useful theoretical idea that has gained widespread adoption in educational discourse is that of the zone of next (or proximal) development (ZPD), proposed by Vygotsky (1978). Vygotsky distinguished between what a learner could currently achieve unaided (their zone of actual development, ZAD) and what they might achieve with suitable 'scaffolding' from a teacher or more advanced peer (in their ZPD). Vygotsky's argument was not just that development takes place when working beyond the 'comfort zone' of what we can already do well, but also that within the same class students who appear to have similar ZAD (i.e., seem to be achieving at much the same level in terms of tasks that have been mastered) may have quite different ZPD and therefore need different levels of support (and challenge) to move them on.

Whilst it is possible to find much writing about the idea of the ZPD (and, indeed, different interpretations of this idea) there has been little research in science education to actually demonstrate (or test) Vygotsky's claim and see how it can be applied in practical terms. This is important, as if Vygotsky is correct, students' scores on tests (undertaken usually unaided and individually - that is working in the ZAD) do not necessarily give a helpful indication of what the learners are ready to achieve next with suitable teaching or peer support (working in their ZPD).

The notion of the ZPD might be considered an example of the kind of theoretical content that populates the 'protective belt' of a research programme (Lakatos, 1970). That is, the principle that '*a student's potential to benefit from teaching depends upon their current characteristics as a learner*' is considered fundamental to, and so irrefutable within, the research programme - but the notion of the ZPD as an effective theoretical tool to characterise learners is what is sometimes termed a 'refutable variant' of the programme. It is considered a *refutable* variant as the notion of the ZPD could be sacrificed without undermining the programme as long as alternative ways of conceptualising how to characterise learners to indicate learning potential could in principle be developed, tested, and adopted.

### **Learning Depends upon Learning Opportunities being Matched to a Student's Characteristics**

Whether the specific idea of the ZPD or some alternative transpires to be the most productive way of characterising students' readiness to benefit from challenging learning opportunities, the second candidate as a tenet for our research programme posits that supporting learning requires a process of matching learning opportunities (and so teaching) to the characteristic of the learners. A clear question for research is *how* to effectively carry out

such matching: how can learning opportunities be matched to students' characteristics so as to best facilitate learning. This question potentially has two strands. In part this is an 'in principle' question looking at how methods of matching can be found which 'work'; and in part this is a practical question of viable professional practice. First research would seek to show this can be done - even if this requires considerable resource (e.g. small class sizes, additional instructional materials). Then research is needed to show how this can be incorporated in professional work as part of normal procedures and practice.

That is, in research we often commit a level of resource to the foci of our investigations (particular classes, teachers, students, institutions, lessons, etc.) that is well beyond the level of resource it would be possible to commit in practice (i.e. to all classes, teachers, students, institutions, lessons, etc.). This is often necessary to systematically study a situation, or to iteratively develop instrumentation, innovations, teaching resources, etc. that allow us to achieve objectives.

Ultimately, however, for research to be useful it needs to be applicable. This candidate commitment for our research programme then indicates something more than seeking 'in principle' demonstration that effective matching is possible. Rather, the ultimate aim is to find ways of supporting teachers (and curriculum developers, etc.) in undertaking effective matching of learning opportunities to student characteristics within the resource constraints of normal teaching: large classes, busy teaching timetables, and limited budgets that make the purchase of special diagnostic tools unlikely.

### **Learners Show a Wide Range of Current Capabilities within any Particular Curriculum Area, and Vary Considerably in Terms of Their Potential for Development with Suitable Support**

That learners show a wide range of current capabilities within any curriculum area is familiar to those working in the education system. Indeed this is an inherent assumption behind public examination systems that seek to certify learners across different levels of achievement, especially when certification is used for selection purposes in terms of progression (such as entry to further or higher education; entry into employment).

That learners demonstrate a wide range of current capabilities can be understood in terms of complementary considerations. What students demonstrate need not be their full potential: some learners take demonstrating their capabilities in class or in examinations more seriously than others. So there are issues of motivation for example (Phillips & Lindsay, 2006) - some students are motivated to do well in tests and examinations, to answer the teacher's questions, to do their homework to the best of their abilities and so forth. Other learners may be capable of demonstrating the same levels of achievement, but are not motivated to do so sufficiently to put in a high level of effort - and so achieve less than more motivated peers.

Moreover, current capabilities are dependent (as suggested above) on learning opportunities. A student can only demonstrate those capabilities they have been facilitated to develop - regardless of their original 'potential'. Of course, this will depend to some extent on what kind of capabilities we are referring to. Some students may have the ability to interpret graphs well despite limited learning opportunities - but they are unlikely to be able to, for example, apply the Brønsted-Lowry theory of acids if they have never been given the opportunity to learn about that theory.

There are cultural differences in this area of thinking within education. In what might be thought of as a Western (e.g. Anglo-American) tradition it is common to think of people as having widely varying inherent potential that is met or not according to opportunities and effort. In this tradition being clever or bright (or alternatively 'thick' or 'slow') is a characteristic of the individual that is relatively fixed and dominates attainment. This idea may be anathema in some Asian contexts where it may be assumed that commitment, engagement and application to a task always bring rewards. Of course such patterns should not be generalised to make assumptions about all students from a particular culture (Ryan & Louie, 2007), but none-the-less students transposed to a different educational context may well experience some dissonance in terms of what is widely taken for granted about the causes of academic success. There may also be gender differences in students' own explanations for their academic successes (or failures) in some educational contexts with boys in general more likely to put success down to ability and failure to lack of engagement, and girls more likely to ascribe failure to lack of ability and success to sheer effort. The phrasing of the candidate for a research programme's hard core commitment here (...range of current capabilities...potential for development...) is intended to leave open the extent to which a students' current achievements or their potential for future attainment may be *partially* determined by factors that need to be considered 'fixed' from an educational perspective. This is an important area that deserves more attention within science education - bearing in mind that however extensive or limited the malleable components may be, it is here that teachers can make a big difference to their lives of their students.

There is clearly a good deal of evidence already available about the range of capabilities students at different levels demonstrate in relation to various learning objectives. What is less clear is how this can be linked to an understanding of the potential that different learners have to make progression in learning from those starting points given suitable support. There is research suggesting how some learners may be constrained by their level of intellectual development from accessing certain types of science learning objectives (Shayer & Adey, 1981) although such notions are by no means universally accepted (Sutherland, 1992). Teachers will also apply their professional knowledge to make judgements about how to manage progression in learning for different students. Yet there is limited clear detailed guidance on *how to* judge a student's potential for learning with suitable support - for example in different areas of the science curriculum.

This is generally true for all learners, but is perhaps most pressing in the case of the students who might be labelled gifted. Where teachers over-estimate the progress students can make, the results (poor learning outcomes) are clear, and adjustments to teaching can be made. In the case of gifted learners, however, it is often likely that teachers will set work which is considered challenging for the class, and which the gifted learners will respond to successfully. This therefore seems a very positive outcome, as these students have risen to the challenge. This may reflect a well-made judgement about what those students are ready to tackle next. However, it could instead simply indicate that there was limited challenge for the gifted learners in the task, and that these students managed to achieve without making the extent of learning gains that they were capable of. If students have been socialised into expecting to work without special effort or challenge, they may indeed be perfectly content in being given, and responding to, tasks to undertake that they can competently and comfortably complete without having to metaphorically 'break into a sweat' - just being kept occupied with 'busy work' (Moursund, 2006). If students have learnt to be sufficiently rewarded by the

external motivators of grades and teacher praise they may lack any insight into how far from their full potential they are being asked to perform.

In the case of individual classes, there is scope for trial and error here: if the gifted learners are readily successful, then teachers can perhaps look to make even greater demands in the next task until a level is found at which they are challenged enough to have opportunities to make real progress. In principle this sounds sensible, and indeed - given the complexity of teaching and learning - good practice is always likely to rely to some degree on this kind of iterative approach, even when supported by a strong research base that provides clear guidance.

However, the reality is that the most gifted learners in many classes are already underperforming in the sense that they have been successfully meeting task demands that were seldom stretching them, given that the gap in *appropriate* teacher expectations between some gifted learners and their classmates is likely to be considerable. This offers a real challenge to the teacher. Some tasks lead themselves to differentiation by outcome. For example, setting an assignment to research the contemporary response to the publication of Darwin's (1859/1968) *On the Origin of Species* is open-ended enough to cover a broad range of abilities (one suspects this has been the topic of more than a few doctoral dissertations). However, there are many topics where there is a significant tension between 'class teaching' and differentiation - especially in contexts where teachers are encouraged to undertake more whole class teaching. So one strategy is to treat a class as a collection of subgroups each of which the teacher works with separately - yet there is much discourse in education suggesting that good teaching is often teacher-led 'direct instruction' (Klahr, 2009; Taber, 2010), and the expectations (of head-teachers/principals, of school inspectors, of parents) of what this looks like may translate to considerable proportions of time when the teacher is working with, and leading discussion of, the whole class (Key Stage 3 National Strategy, 2004). Such expectations may work against effective differentiation techniques. A good teacher can keep a class engaged in an extended discussion - but this may not mean that everyone in the class is both (a) sufficiently understanding the ideas being discussed, and (b) also being challenged enough in their thinking to promote further learning.

Given these considerations, there is a strong need for a research base to find out a lot more about the range of potentials for further learning in different kinds of classes. Without this it is quite possible that norms and expectations about how classes are organised in many education contexts might be necessarily limiting the learning opportunities of some students through teaching that fails to sufficiently challenge their current thinking and scaffold new learning.

### **At any Age or Grade Level there Will Be Some Students Who Are Considerably Further Advanced in Their Science Learning than Their Peers**

The diversity of learners within any cohort or class is clear to all teachers. Effectively pedagogy involves engaging with learners' thinking, and indeed good science teaching is very much an iterative process where the teacher is operating with an (often implicit) model of what the learner already knows and understands, and so pitches information, questions, tasks accordingly - and then uses information about how the student responds to inform modifications of that internal model (Taber, 2013a). This is at the basis of learning that is



sometimes referred to as constructivist (Taber, 2011), but which is also sometimes labelled as learner-centred (or even 'progressive'). Unfortunately such terminology is not used in uniform ways in educational discourse - and terms such as constructivist and progressive are seen by some as bywords for ideologically driven approaches that undermine ordered teaching (Kirschner, Sweller, & Clark, 2006). That is misinformed, as constructivist teaching done well is not *laissez-faire*, but is rather teaching that is matched to students' current learning needs (with an optimal level of guidance), and which moves between teacher-led and student-led activities in a planned and structured way (Taber, 2013a).

Anyone teaching in an interactive way (and arguably non-interactive teaching is an oxymoron - and is no more than presenting) soon becomes aware of the diversity of capabilities within a teaching group - even when working with what is labelled - for example - a top set. Indeed if we assume that within any population different capabilities are likely to follow a distribution something like a normal distribution (as suggested above) then we might expect those groups which contain the learners considered most able (and to some extent also those groups which contain the learners considered least able) to show the widest variation. So for example, on an IQ test there will be many scores clustered near the mean, such that a proportion (e.g. 10%) of individuals with scores closest to the mean will have a modest spread of scores. However, the same proportion (e.g. 10%) of individuals at either tail will show a much greater range of scores.

### **These Students May Sometimes Be Referred to as Gifted in Science**

Terms such as gifted, or gifted and talented, are commonly used to refer to these students - although other terms such as highly able may also be used (Cropley & Dehn, 1996; Department for Education and Skills, 2002; Sternberg, 1993). However, there is little agreement on nomenclature or how to define these groups in the literature. In this chapter the label 'gifted' has been adopted as it is commonly used and is widely understood at least in general terms. Part of the work of a research programme will be to clarify and adopt terminology and nomenclature that can be readily used across an international community of researchers.

### **Science (And Science Subjects) Present a Broad Range of Learning Challenges Such That Many Students Will Have an Uneven Profile of Current Knowledge, Understanding and Skills**

Another issue of importance in science teaching is that science is itself quite diverse (Jenkins, 2007). There is certainly commonality across the sciences - at least in terms of a mindset that informs a way of going about science. However, the subject matter of science is extremely diverse (being, in principle, all of nature) and the methodologies adopted are similarly so - with some sciences being highly experimental, some largely based on observation; some being mostly laboratory based, and others relying on fieldwork. Even within a science, there is a considerable range in what is required of a learner.

Chemistry can be considered as an example. Chemistry is a subject that involves a good deal of laboratory bench work, requiring good manipulative skills (as well as an understanding of why and when to use those skills) as well as a diverse body of theory to be mastered. The content of chemistry has traditionally been structured through the main branches of inorganic, organic and physical chemistry (even if such distinctions are slowly being broken down), and each of these has its own 'feel' and nature. Physical chemistry relies a great deal on mathematical modelling, and tends to deal with general principles and theories that can be applied to a wide range of chemical systems. Inorganic chemistry has a very strong link to the periodic table as the basis of a system of classifying substances through what can be a very ordered series of typologies. The mind-set for excelling in physical chemistry is surely somewhat different from that required to master inorganic chemistry. Organic chemistry is in some ways more akin to inorganic than physical chemistry - being organised through classification systems based on actual substances and reactions rather than general theoretical models. But there are still very real differences between these two branches - in part due to the complexity of the range of organic substances that exist (or can be brought into existence). It is quite conceivable that a learner considered gifted in physical chemistry might not show such exceptional ability in organic chemistry - or *vice versa*. Similarly, those who excel in theoretical chemistry may not be especially skilled at the bench. Moving into biochemistry or pharmaceutical chemistry crosses further disciplinary borders.

It is important therefore not to simply consider that some students are gifted *per se*, or even gifted in science *per se*, or even gifted in chemistry (or biology, or physics, etc.) *per se*. In practice many students may have areas of current capability worthy of a label such as 'gifted' (and so likely to benefit from particular curriculum or instruction) whilst in other areas within the subject their current capabilities may be unremarkable. Ideally education not only matches level of demand to capabilities of students in general, but actually looks to give all learners opportunities to make good progress across different learning goals - including more challenging work in those areas where they show high levels of current achievement.

That said, a different argument might be that all learners should be supported to develop across a wide range of education goals, and that where learners show uneven development it is more sensible to focus learning opportunities in areas where that student is *less* advanced. This could be a sensible argument for example when teachers are working with 'twice exceptional' students - those who show exceptional capabilities in some areas, but may also demonstrate specific learning difficulties (Sumida, 2010; Winstanley, 2007). Perhaps a student shows exceptionally high levels of knowledge and logical thought when working orally, but has specific learning difficulties that make producing written work problematic. In such a situation it could make more sense to focus educational support on developing better writing skills given how important these are likely to be to general academic success. Even here, it is questionable whether support to overcome a learning difficulty should preclude opportunities to make good progress in an existing area of strength. In general there is an issue here of the extent to which education should aim to facilitate the development of well-rounded learners with broad areas of capability, rather than seek to identify and nurture exceptional talent. Undoubtedly both are important aims, but in particular cases judgements need to be made about where to focus educational support and where to direct the precious resource of the learner's study time.

Informing such judgements requires evidence-based knowledge. Mozart's prolific talent was nurtured by opportunities to extend himself in music from a young age. In retrospect we

might judge the young Mozart's education was unbalanced - but we may not think that he would have been better served (or that the world would be a better place) had the authorities persuaded the young Wolfgang's family that he should spend less time on his music to develop his knowledge and skills across a much wider range of subjects and activities! Darwin was not identified as an exceptional scholar when he was young, but he had an intense fascination with natural history, seemingly at times to the detriment of his studies of the wider curriculum. With the benefit of hindsight it seems clear now that Darwin was a gifted learner in the sciences — but then hindsight is itself said (sarcastically) to be a wonderful gift! Research is needed to better understand the profile of capabilities (and potentialities) brought to science learning by learners in general, and those we might label 'gifted' in particular.

### **Science Provision Needs to Offer Suitable learning Opportunities to Allow Students (And in particular Here, Gifted Students) to Make Progress in Their Learning**

As suggested earlier in this chapter, there are very good reasons to be concerned about the educational provision provided in science education for those considered gifted in science. These students are a resource for society, having particular potential to contribute to future scientific and technological advances in a world facing serious problems (some of which are due to the - historically unprecedented - scale of human populations and the resource implications of the lifestyles people aspire to).

Moreover, there is a moral issue in considering the nature of education for the gifted. If society takes responsibility for the education of its young people, and (as it often does in modern societies) makes education not only an entitlement but also compulsory for those within a certain age range, then that society has responsibilities not to waste the time of the young whilst attending school. Compulsory education must bring an entitlement to provision that supports meaningful and substantive learning. That is, if we require gifted students to be in school, we should ensure school offers them opportunities to fully benefit from being there that make their attendance worth their while. Yet it is suspected that in many educational contexts, gifted students spend much of their time 'treading water' - undertaking 'busy work' which does not engage their creativity or challenge their thinking. Educators should not have the right to waste the time of those who are required to attend our classes.

Research therefore needs to support teachers and curriculum developers to provide gifted learners in science with suitable provision to give them the opportunities to make genuine progress in their learning. There are already many studies that report offering particular inputs for gifted learners (whether within normal classes, in gifted streams, as enrichment in the school outside normal curriculum, or as special programmes attended away from the home school). This research is theorised to different degrees, and evaluated at various levels - some programmes have been subject to extensive systematic evaluation, but this has often not been possible for many small-scale initiatives.

The question for the research programme is what forms of provision do genuinely offer suitable learning opportunities to allow gifted students to make substantive progress in their science learning. The programmatic nature of the research is such that for this question to be effectively tackled, research needs to have already made progress on developing theory

around some of the earlier core commitments (so that researchers are able to characterise the students they are working with and their potential for further learning).

### **Particular Science Provision is Indicated for Those Learners in Any Cohort Who Are Too Advanced to Find Substantive Learning Opportunities in the Standard Provision**

Implicit in this last point is that - given some of the ideas already developed - it is not reasonable to assume that standard educational provision - normal curriculum taught in normal classes - offers sufficient scope to challenge the most able learners and support their development and learning progression. The question suggested by this candidate for a research programme hard core commitment is clearly along the lines of *what are the particular kinds of provision which are suitable for gifted science learners, that allow teachers to match instruction to these students' readiness for further learning*. As with the previous point, progress here is dependent upon having a good understanding of the current capabilities of learners and how these can act as the base for further learning that taps into students' potentialities.

This question needs to be explored within wider concerns. To what extent is it desirable to separate out gifted learners from their peers either physically (by teaching them in a different place) or marking them out through setting them clearly different work to others in their class? It is argued that gifted learners need to work with others of similar characteristics to engage in the kinds of peer dialogue that will support learning and engage them in subject matter (Taber, 2007a) - and, sometimes, gifted learners may be - at least to some extent - socially rejected by those who regard them as too nerdy or geeky. Indeed it is sometimes claimed that many gifted learners may deliberately underplay their capabilities to better fit in socially with their classmates. Yet some gifted learners do manage to fit well within heterogeneous classes, and setting up separate classrooms for the gifted (even where numbers make this viable) may only encourage a sense of otherness and difference.

Gifted learners will hopefully develop into gifted adults who contribute to society, and often this will mean socially engaging effectively in the workplace and wider community with others who may have very different intellectual characteristics. Too much separation from a diverse range of peers during formative years may make successful transition to adult social contexts more difficult.

Another problem with setting up a gifted stream - or even gifted school - is that it is based on the dichotomous notion that some learners *are* gifted and some are *not*. Much of the presentation that has led to this point in the chapter has argued that there are gifted learners who have quite different characteristics than most of their peers - *in some regards*. Yet it has also been suggested (a) student capabilities tend to lie on broad distributions, so there is not likely to be a clear gulf between groups of learners classed as 'gifted' and 'non-gifted' (even when there is clear gulf between *some* learners who may be classed as 'gifted' and *some* of their peers) and (b) that learners often have an uneven profile of capabilities, even within science, so they may be gifted in the context of some topics or skills areas, but not others.

Moreover, there is a wide suspicion in some education systems of any kind of labelling and segregation of individuals because it can itself bring about effects (Rosenthal & Jacobson, 1968). In the English system of state-funded secondary education set up in the 1940s it was

decided to provide different kinds of schools for different kinds of learners. As a result of a test taken one day in the final year of primary school students were (in effect) labelled as academic or not. This system was later abandoned because it was realised that whilst it was not possible to identify academic potential in such a simplistic way, the assignment of a learner to the non-academic school made it extremely unlikely that learner could ever work their way back into the stream being prepared for university entrance examinations or possible entry to the professions - especially when such learners came from less advantaged socioeconomic backgrounds. It was not impossible to switch school type after eleven, but the expectations and different provision in the 'modern' schools made it very unlikely a student there would be found to be working at a level sufficient to be able to be unproblematically moved to the 'grammar' school (Taber, 2012b). Moreover, certainly in the British tradition, the notion of different kinds of schools suited to different kind of learners was widely seen as implying something about the worth of the learner and the work they were being prepared for: grammar > technical > modern.

Some of these issues are avoided when learners remain in the same classes but are set different work. This may also be seen as divisive, however, if a few 'gifted' students are given something different to do than the rest of the class - especially if they are given something perceived as more interesting that 'gets them out of' doing the more routine work assigned to the rest of the class.

This scenario also has the potential for leading to a situation where most of the teacher's time is spent dealing with the default work in the class, with only occasional forays to see how the gifted learners are getting on. We might expect gifted learners to have more advanced metacognition (but not necessarily, given the point about different profiles that students may have) and we might feel that being given more expansive tasks that need to be planned and managed by the learner with less teacher input is a good thing (Shore & Dover, 2004). In general this is likely to be so (Taber, 2007a), but if we adopt Vygotsky's notion of the ZPD (as discussed above) we will also be aware that learners are facilitated to make the most progress when scaffolded by a more experienced person (such as the teacher).

One possible direction for research is exploring opportunities to employ the most advanced students as teaching auxiliaries in classes. This must not be (as in the Victorian schoolhouse model whether older students acted as 'monitors') simply a means of 'using' gifted students as a (cheap) supplementary teaching force, but rather recognising the value to learning of having responsibility for teaching others.

The focus would be on how preparing for and actually teaching others can support the development of a better-integrated and deeper understanding of subject matter for the 'teacher' (Taber, 2009a). This approach allows the development of personal organisation, metacognitive and social educational objectives as well as conceptual learning - but will not suit all gifted learners, and possibly is more feasible in some curriculum topics and educational contexts than others. This is just one suggestion for a line of research that can be developed.

There are then considerations that pull us in different directions - and that is why research is needed to test out these different considerations in various educational contexts to find out what kind of provision best meets the (intellectual, and other) needs of gifted learners in science - or indeed different kinds of gifted learners doing various kinds of science learning. Conceptualising such research within a common overall programme (perhaps along the lines suggested here) can help to build coherence between isolated studies.

## CONCLUSION AND RECOMMENDATIONS

The argument made here is that

- a) there is a pressing need for the science education community to focus coordinated research attention on the issue of teaching the highest achievers, the gifted, in science;
- b) areas of enquiry make progress through the establishment and development of well-defined scientific research programmes (Lakatos, 1970), which clarify core assumptions and establish lines of work consistent with those assumptions; so
- c) there is value in setting out the starting points for a research programme exploring educational provision for the gifted in science.

One issue that this characterisation of the field has attempted to highlight is the problematic nature of the label of the gifted learner (in science, or more generally). A progressive research programme has to respond to important issues around the discomfort of many educators in some educational contexts of labelling students with terms such as 'gifted'. The term itself is considered inappropriate by some due to its traditional meaning of having been given a gift by fiat. This suggests people 'just are' gifted (or not) through the accident of who they happen to be, and there is nothing they or anyone else can do to change that. Most educators believe, based in part at least on the evidence of educational practice, that people have considerable potential to develop - and indeed that labelling people may lead to expectations (in teachers and students, in regard to those judged as gifted, and those judged as not gifted) that can in themselves have effects.

The approach taken here is to argue that giftedness/non-giftedness should not be seen as a dichotomy where decisions will always need to be made about 'cut-offs' within a spectrum of attainment/potentiality, and that giftedness is never an absolute but is always a judgement made relative to some specific context. The learner who is not considered gifted this week in the context of learning about human anatomy (because the standard curriculum provision is suitably demanding) might deserve to be considered gifted next week in the context of studying the gas laws (because these seem intuitively obvious to her and the standard scheme of work on this topic presents no challenge to move her thinking and understanding on), and may indeed be considered gifted in two years' time when anatomy comes around again in the spiral curriculum (as in the meantime she has developed a burning desire to enter medicine and has been obsessively reading everything she can find about human anatomy and physiology).

So the notion of giftedness proposed here is a pragmatic and constructive one: in terms of a need for special attention to ensure opportunities are provided that can be genuinely educative for the particular learner when the standard curriculum to be presented to the wider group of learners does not offer a match in terms of the gifted learner's current state of learning and potential for further progress (in the particular subject, topic, or even activity). Whether individual teachers are comfortable with using the term gifted or not, this is an issue of educational equity - all learners in a course or programme of study are entitled to be provided with genuine opportunities for substantive further learning.

One radical take on the characterisation of the research programme offered here is that it is largely not about gifted learners *per se* at all: but rather is about the need for science teaching that better reflects individual differences. All students are different, all come to class with unique resources for learning: they all know somewhat different things, have different levels of understanding of topics, different interests, different sets of 'alternative conceptions', different aspirations, and - in terms of the discussion above - very different profiles of current strengths and weaknesses (and of current potentials for immediate progression) across and within curriculum subjects. The logic here then might suggest that the notion of gifted learners is both distracting and unnecessary. Responding to the general challenge of identifying students' potential for learning and matching this with suitable learning opportunities would solve the issue of the learners who might be considered gifted in certain learning contexts without needing the label or inviting issues of cleaving the gifted from the non-gifted as an unjustified dichotomisation. Whether such a general programme would risk losing sight of the particular needs of those who are genuinely outliers on distributions of current capability and immediate potential for further learning is a moot point.

Of course it is not assumed that because someone working in a field promotes a particular model for a research programme (such as that described here) that this will necessarily be taken up by others working on the topic. The fundamental commitments of a research programme have to be shared by those working in a field - they have to be committed to! - and they cannot simply be imposed. Perhaps some colleagues would disagree over some of the suggested commitments here - either radically, or at least in detail. This chapter has argued the case for the need for seeing this important area of work in terms of a research programme, and has put forward what seems a reasonable characterisation of the basis of that programme. If others with interests in this area are provoked to disagree over specifics of this proposal, but within a mindset of seeking to establish common ground across researchers, then at least the argument here might initiate fertile conversations about how to best understand this important area of research.

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