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From each according to her capabilities; to each according to her needs: fully including the gifted in school science education

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ABSTRACT

All students should be entitled to educational provision which they can access and which challenges them sufficiently to support their development. In any class in a public education system there will likely be a small proportion of students for whom the provision offered for most students will fail to challenge them in any meaningful way. These 'gifted' students may not obviously be excluded as they will typically engage (albeit, not always in very deep ways) with teaching and they will usually perform well on objective assessments of academic achievement. Indeed they will often significantly out-perform their classmates – which may be interpreted as evidence that they are benefitting from instruction. Yet often the most able learners are not being meaningfully challenged in class, and so are not being supported in ways that match their educational potential. This chapter considers the nature of this problem, and some of the complexities around it, as well as exploring how learners who are gifted in science can be fully included in science education. Accepting that the notion of there being 'gifted learners' is sometimes considered unsound, divisive, and elitist, this chapter adopts a nuanced but pragmatic notion of giftedness (i) as always relative to some particular learning context; (ii) as open to degrees of giftedness; and (iii) as a judgement made at a particular time in relation to some particular educational episode rather than for all time. It is suggested that the area of giftedness in science learning has been under-researched but a number of classroom strategies are recommended. These include designing class learning activities with high demand, but then using scaffolding to offer differentiation by support; extension work for gifted learners with a focus on creative production and knowledge integration; and involving gifted learners in a peer tutoring role in ways that facilitates learning for the tutor as well as their peer. The chapter is underpinned by a belief that failing to offer gifted learners who are required to attend formal schooling a form of educational provision that is genuinely educative for them is not only detrimental to these learners and the wider society, but is unacceptable on moral grounds.

INTRODUCTION

This chapter is informed by experience of teaching and working in the English curriculum context, but discusses an issue that is giving concern to science educators in many other national contexts. The premise of the chapter is that all students should be entitled to educational provision which they can access *and* which challenges them sufficiently to support their development. Barriers to access may be understood here in a number of ways such as not being enrolled in school; lacking the language of instruction; having a physical or mental condition requiring support that is not provided; lacking the literacy levels to understand dialogue or text; or lacking essential prerequisite 'prior learning' needed to understand the class. Each of these, and other, barriers to accessing teaching and engaging in meaningful learning are issues of major concern with some groups of students, and these issues are discussed in other chapters in this volume.

The present chapter considers another group of students who *are* able to attend school and receive instruction readily, and so would seem to have no barriers to accessing the education they need. However, these students – sometimes labelled as gifted and/or talented, or the highly able – are often not able to access the teaching they need, and we would argue are entitled to, because of a lack of match between provision and their 'special (i.e., particular) educational needs'. Just as teaching in English does not match the needs of a recent refugee from a war-torn African nation who has minimal or no English when they enroll in a school in an English speaking country; or just as being placed in an advanced class does not match the needs of a student who has not completed introductory and intermediate classes and so cannot access the ideas being discussed; in the same way teaching that does not offer anything to challenge and develop the ideas of a student who has already progressed well beyond most classmates does not meet the needs of that learner for genuinely educative experiences.

This is an issue that is important across different educational systems and not just in science classes. In any public education system there will be a small proportion of students for whom the provision offered for most students will fail to challenge them in any meaningful way. These 'gifted' students, may not obviously seem to be excluded in any way, as they will typically engage (albeit, not always in very deep ways) with teaching and perform well on objective assessments of academic achievement. Indeed they will often significantly outperform their classmates suggesting that they are benefitting from instruction. Some gifted students may themselves seem satisfied with that – after all the system is setting them learning tasks, and they are performing well and receiving praise for their efforts – and they may judge their own performance in terms of perfect or near perfect scores in tasks which largely rely on rote learning and straightforward application of previously learnt material.

This is of course more likely when the learner has an external focus for motivation, or has never experienced and so appreciated the value of learning that is difficult, calls on extended engagement, and leads to success slowly. After all, for the student who has consistently been awarded high marks since their earliest exposure to studying science without needing to commit too much resource to their work, there is little basis to appreciate either how atypical this is, nor why having to sometimes struggle with tasks of high demand is ultimately a positive thing. Other highly able students may be satisfied with the status quo because they value needing to put little effort into their work, and perhaps focus their creativity into activities outside their science studies. Such students are sometimes labelled as lazy. However this may be unfair if they have over time simply learnt to adapt themselves to the reality that their best efforts are seldom needed in science lessons, and so there is more satisfaction to be found in what are experienced as more challenging areas of activity (be that in other school subjects or beyond the formal curriculum). One study identified a subgroup of about a fifth of gifted learners who typically lacked persistence when faced with challenge because they had low perceptions of their competence and so low expectations of themselves despite being recognised by their teachers as high achievers (Phillips, 1984).

Certainly, there is now considerable evidence that often the most able learners are not being challenged in class, and so are not being supported in ways that can best facilitate them in making substantive progress in their science learning (Gallagher, Harradine & Coleman, 1997; Rogers, 2007). This chapter considers the nature of this problem, and some of the complexities around it, as well as exploring how learners who are gifted in science can be best fully included in science education. The next section of the chapter considers some of the problems around notions of giftedness, and possible reasons why this group has not always had the attention it deserves.

QUESTIONING THE GIFTEDNESS CONCEPT

It is certainly the case that there has been some uneasiness around the notion of giftedness among some professionals working in education and this has perhaps been reflected in the relative lack of attention to this area as a research topic within science education. Moreover, as there is now an established area of educational activity labeled as 'gifted education', there is potential for ambiguity over whether work looking at the gifted in science best belongs as part of gifted education or science education. Reservations about the need for a particular concern with the gifted in science seem to revolve around several issues, including the terminology, the ontology, and axiological considerations. Here we discuss these themes sequentially, but the perspective we bring to the topic suggests that these matters are strongly connected.

The contentious nature of giftedness

The term 'gifted' is widely used, but not universally, and nor does it have a generally agreed meaning. Sometimes the term is used alongside 'talented' (the 'gifted and talented') either as a kind of collective term (Subotnik, Olszewski-Kubilius, & Worrell, 2011), or - in the example of the English curriculum context (Department for Children Schools and Families, 2008) - to set out two groups of students (in that case those who show most ability in academic subjects; and those with high levels of performance in areas such as the arts and sport). However, in some contexts terms such as 'the highly able' are used rather than 'gifted'. Such lack of agreement on terms within the educational community is not ideal. Moreover, some find the terms gifted and talented to be objectionable because they are seen to bring with them associations that many educators are uncomfortable with (Gagné, 1995; Koshy & Pinheiro-Torres, 2013). That is, due to how these terms were once commonly used, the terminology may be considered to imply that some people have been given (e.g., by God) particular gifts or talents that others do not have - and so that being gifted or not is a dichotomous and rigid construct (quite different to the approach taken in this chapter, as discussed below). Such associations may be unfortunate, but language is fluid and word meanings change over time. As the term 'gifted' is commonly used to denote those who have demonstrated particular ability in an area, and as there is not a clear commonly used alternative, we will use this term in this chapter - but wish to be clear that we do not see a judgement of giftedness as either an absolute nor as a fixed categorisation.

That leads then to the next key issue of what is meant by suggesting a student is gifted in a curriculum area such as science, and again even when the term is widely used there is no

clear understanding that is widely shared (Gilbert & Newberry, 2007; Sternberg & Davidson, 1986; Taber, 2007c). In some contexts the notion of the gifted is reserved for those rare few who are considered to clearly have qualitatively different levels of aptitude for science than their peers. In other contexts the term may be more inclusive, intended to refer to some more generous top percentile. So in the English curriculum context schools are asked to identify their top 10% of students in each year group as being the gifted. Here there is no expectation that there is anything qualitatively different between gifted and non-gifted as a somewhat arbitrary cut-off is imposed. Moreover, under this regime there is no expectation that being (or not being) labelled as gifted has any absolute meaning beyond the local (i.e. particular) school context. Schools can draw on very different catchments and so a student who was labelled as gifted in science at one school might find on moving to another part of the country that in their new school they are no longer considered gifted in science in the context of their new peers (and the opposite transition is also feasible). Here then giftedness is a pragmatic concept used to encourage all schools to pay sufficient attention to the learning needs of their highest achieving students rather than a highly theoretical concept linked to any specific attributes or qualities.

Whilst such a pragmatic approach seems rather atheoretical, and lacking a strong basis to inform science pedagogy for the gifted, it does rather stand in contrast to notions of gifted students as being something special and different from others – and in particular being within a fixed ontological category. If a student can move in and out of being considered gifted then there is clearly no assumption of assignment by fiat, or of a particular person's genetic make up (for example) determining that they will (or will not) be gifted in science. This is important as the notion that gifted learners stand apart from others as a distinct and fixed category is something many educators find objectionable. Indeed some would go as far as rejecting the notion of labelling students as gifted, or similar, under any circumstances because of the potential for labelling to itself have effects through the expectations it raises in students and teachers (Rosenthal & Rubin, 1978) in relation to both those given the gifted label and their peers who are by default effectively labelled as 'not gifted' in the subject.

This is one reason why some colleagues are uneasy with the notion of identifying gifted learners in science. Some teachers are rightly suspicious of any labels we apply to learners in part because it is known that such labels can have effects, and in part because it may seem to undermine an outlook on teaching that it is important to value each learner as an individual (Cross, Coleman & Stewart, 1993; Cross, Coleman & Terhaar-Yonkers, 2014; Freeman, 2013). Students in science classes are diverse in many ways (Mansour & Wegerif, 2013). Each student is unique, with their own strengths and weaknesses; their own aptitudes and interests; their own ways of engaging in learning, and their own personal unique learning progression pathway (Gardner, 1993; Snow, 1997). Consequently, each learner has his or her own optimal ways of learning and developing under guidance from a teacher.

We fully accept this perspective, and would tend to agree with a view that from such a position the use of labels such as gifted could become irrelevant and potentially distractions. Indeed the rationale behind this chapter is very much in keeping with such a position – all learners are unique and different, and so teaching needs to find ways to reflect this. Yet it can be very difficult for teachers to effectively find ways to respond to the twenty or thirty (or sometimes more) unique learners in their classes, and some schools, some curriculum contexts, some education policy contexts support teachers better than others in this regard. As one example, there has been a major debate in educational research and policy circles on the role of 'direct instruction' in effective classroom teaching (Taber, 2010; Tobias & Duffy, 2009; Tobias, Kirschner, Rosenshine, Jonassen, & Spiro, 2007). Some governments are adopting the view that proper teaching involves a good deal of the teacher standing in front of the whole class and talking to them. Now effective pedagogy is never likely to be represented by

one mode of teaching and high quality science teaching is certainly likely to include periods of teacher-led talk with the whole class (Mortimer & Scott, 2003) – if coordinated with students working alone, and particularly, in groups (Scott, 2007). However, encouraging teachers to spend more of their lesson time in whole class teaching surely limits the teacher's ability to meet the individual needs of all those unique learners who make up the 'whole class'.

Ideally then teaching would be an inclusive activity that would focus on the individual qualities and needs of each student and would in effect be blind to general categories such as gender, ethnicity, first-language status, disabilities, and indeed gross categorisations based on intellectual ability. If ever this is achieved, if indeed it could ever be practically achievable, then the 'gifted' label would have no value, and books such as the present volume will be only of interest to the educational historian. At the present time, however, there is a problem in many educational systems of schools often failing to effectively meet the needs of the most able in science.

GIFTEDNESS AS AN INCLUSION ISSUE

At this point then, we have acknowledged issues with the giftedness label, yet for pragmatic reasons retain it (i.e., most colleagues appreciate in general terms what is denoted by 'gifted in science', Koshy & Pinheiro-Torres, 2013) whilst having not yet offered our own notion of what the term *should* be taken to mean. Our own take on what it is useful to mean by 'gifted in science' is a pragmatic one, as we explain here.

The crux of the issue concerns the purpose of education. If we understand education as about the transfer/acquirement of an identifiable knowledge base and skill set, which has been judged necessary for the learner and/or the society in which they live, then it is clear there is no problem of gifted learners. Some students readily attain the prescribed 'standards', the levels of knowledge and skills to be considered schooled (by such a criterion) and we may consider them successful learners and/or consider the teachers and schools as being successful in educating those learners. From this perspective the issue is not with *these* students, but *those others* who fail to acquire the knowledge and skills set out as the minimal standards expected on completing school. Perhaps these are failing students, or perhaps they are instructed by failing teachers, or perhaps they are in failing schools – wherever we wish to assign 'blame', this is considered the problem in the system where attention is needed. In some cases the students who fail are considered to face barriers to learning that require extra resource. 'Successful' students (in these terms), however, are clearly managing with the resources already available to them.

Now we would certainly not accept the premises of this analysis, and we suspect that when presented in these terms few teachers, parents, or educational policy makers would adopt such an analysis as the basis for ignoring gifted learners. Yet for many years this kind of argument actually had considerable influence in some educational contexts (Taber, 2012). Policies focused resources on those seen to be falling behind, and teachers would actually comment that they should focus their time on the low achievers, and that this was in part possible because the most able learners did not need much help and were actually able to manage perfectly well with minimal supervision. It is indeed the case that some gifted learners have strong autodidactic capabilities, and differentiation by support is of itself a perfectly respectable pedagogic tool – but this is not an acceptable situation when the most able do not need help simply because they are never given work which genuinely challenges them.

Probably few working in education would see the primary purpose of the enterprise as being about the transfer/acquirement of an identifiable knowledge base and skill set, which has been judged necessary for the learner and or the society in which they live – yet a good deal of custom and practice in many educational systems give the impression that these systems have been designed in those terms. Curriculum is often set out in this way, and even if "we are all constructivists now" (e.g. Ernest, 1995: 459) and few teachers believe knowledge can simply be transferred from their own minds to their students' minds (Taber, 2009b), much of the everyday business in many classrooms seems predicated on the assumption that this is what teachers should be trying to do even when a vast research base in the learning sciences and science education clearly shows it is not a productive way of thinking about teaching.

Meeting the scientist supply needs of the economy

Here we consider two other ways of thinking about the purpose of education. The first is also somewhat pragmatic: that society needs people to occupy particular economic roles, and education is – in part at least – an enterprise set up to ensure the supply of future citizens able to take their place as responsible adults who contribute in various ways. The immediate concern here would be that sufficient people should choose to study science to become scientists, engineers, technologists, medical professionals etc. We also, of course, want all those leaving school to have enough science background to make informed decisions as consumers, as voters, as medical patients etc. That science for citizenship issue is certainly very important (Millar & Osborne, 1998), but it is the supply of future specialists that is more pertinent to the theme of this chapter.

We would suggest that there are three aspects of science education that are necessary to provide the supply of future scientists. One is that enough science in school is taught to prepare learners for entering higher level elective courses, and another is that there is a means to discriminate those with high potential to be successful in such areas of work from those with less potential (e.g., see the chapter about Super Science High Schools in this book). In terms of how much science needs to be taught, or which science, we have very little to say because this is somewhat arbitrary. Often school leaving qualifications are largely based on what higher education institutions feel they need to set out as a starting points for degree level courses, but in practice university teachers often expect to need to go back over key prerequisite materials for their courses, and in principle there is no reason why degree level courses could not be designed to start from whatever endpoint for schooling that it was decided made sense in terms of teaching school age learners!

More important is our third requirement, which is not about the system choosing future scientists for the economy, but in the choices the young people themselves make about their futures. Schooling needs to provide young people with a reason to think that science is for them. Here there may well be a problem in many educational systems. Many young people (especially prior to adolescence) find themselves attracted to science or some science subjects or topics. As science educators we start from a position of strength: science covers a multitude of fascinating topics and ideas. Some of those young people retain their interest – finding school science, relying upon extracurricular activities to supplement what may seem a dry experience in the classroom. Some move away from science as part of their personal response to changes that naturally occur during adolescence – and as they discover new potential areas of study.

That some young people's interests shift from science as they mature may be considered quite natural. However, school science is not actually science but a representation of it, and

there are choices to be made about how we wish to represent science in schooling to give an authentic taste of science that will appeal to learners. We know that many students see science as largely about facts (and school science as about learning lots of them) and see much of science as already mapped out established knowledge. That may not appeal to a good many young people ('gifted' or otherwise). If science is presented as being largely about facts, and about learning and applying existing theories and laws, then this offers limited scope for ingenuity, creativity, and indeed genius. By comparison, some other areas of the curriculum such as literature and social sciences would seem to offer much more scope for original thought. Science may be set out as reductionist, analytical, and about seeking to control nature. It can be all those things, yet science also has holistic, synthetic and creative aspects (Roy, Forthcoming; Taber, 2011), and is inherently more about understanding rather than controlling nature. These are areas where it is recognised that many female students may be engaged or disengaged depending how science is represented and perceived (Bentley & Watts, 1987; Rolin, 2008; Taber, 1991).

The effect of how science is presented on students' engagement will be complemented by the response to pedagogy employed. Science can be taught as a rhetoric of conclusions (Schwab, 1962), to be regurgitated and applied. This will be a task readily undertaken by those with good memories, the mentality to readily adopt and use algorithms, and those prepared to put in the time to learn the material and practise answering assessment questions. This not only offers a limited view of the nature of science itself, but also hardly represents the nature of work as a scientist. Importantly such school work will offer limited engagement to those students who find such tasks routine and so can be successful without needing to engage deeply in the learning activities. What these students lack is the kind of challenge which can lead to that deep level of engagement that has been labelled flow (Csikszentmihalyi, 1988), which makes learning exhilarating such that the learner is likely to actively seek out more of the same (Taber, 2015a). So from our societal perspective on the purpose of education – as providing people to take up key economic roles – there is clearly a danger that education is failing to encourage many potential future scientists to consider careers in science if learning science is experienced as a pedestrian activity.

Meeting the needs of a liberal education

We can also consider this issue from the perspective of a different notion of the purpose of education. Perhaps education should be about the learners themselves – especially when they may be required to attend a decade or more of compulsory schooling. How does a free, democratic society justify requiring children to attend school? Historically this would not have been an issue as minors were expected to allow adults make decisions for them – but these days we recognise that children have human rights, including the right to influence decisions made about their lives (Jenkins, 2006). Parents, teachers, and governments all have responsibilities in making such decisions to consider the needs of those learners.

Arguably an important purpose of education relates to its value to the individual learner. As educators we believe in the value of education for the development of the person, and the value of a liberal education in offering the individual learner opportunities to experience all key areas of culture (which would include science) – through opportunities that are truly educative. That means that educational activities should contribute to the intellectual development of the learner. That in turn means much more than simply building-up an extensive knowledge of subjects. A strong knowledge base can support developing expertise, and higher levels of intellectual ability and metacognitive ability can support the process of building up more extensive – and better structured and integrated – knowledge (Taber, 2015c). However that does not imply that teaching that provides opportunities to construct

new knowledge automatically support the student in developing either their intellectual skills or indeed their metacognitive abilities. As suggested above, some students considered gifted are strong autodidacts – they seem to have worked out how to learn effectively and manage to do so without explicit tuition. Some such learners will challenge themselves in their learning and provide the conditions for their own development – but these students may be the exceptions, even among those commonly considered gifted (Tang & Neber, 2008).

Rather, most learners will only develop their intellectual skills with suitable support (Vygotsky, 1978). It is the role of the teacher not only to teach the curriculum in terms of topics, but to seek to ensure that all students are set work which is both accessible and challenging. Without being regularly pushed to go beyond what can comfortably be achieved there may be much learning of specific material, but limited development of new ways of thinking and learning. This is the basis of the notion of scaffolding (Vood, 1988), deriving from Vygotsky's (1978) theory of the zones of actual development and next (proximal) development (ZPD) – that what is most significant for education is not what the learner can currently achieve unaided, but rather what they cannot yet do alone, but can begin to do with suitable support. It is this working outside the comfort zone, but in the ZPD, which allows what is not quite yet within grasp to be vicariously experienced, modelled internally, achieved in parts, and developed towards personal competence (and perhaps eventually expertise).

The adage derived from Vygotsky that new learning always has to be experienced first at the interpersonal level on the social plane before it can be experienced at the intra-personal mental level may be an exaggeration, but in general most learners will not typically work their way through new challenges without support unless they first spend unproductive amounts of time repeatedly failing before succeeding. Yet scaffolding can help match the challenge to the learner and facilitate development. That this is not just educational wishful thinking has been demonstrated in work such as that of the Cognitive Acceleration through Science Education programme where asking lower secondary students to work, with suitable support, on science tasks requiring (what in Piagetian terms are called) formal operations has been found to have positive outcomes for later academic achievement well beyond science (Adey, 1992; Adey & Shayer, 1994).

There is a clear challenge for overworked teachers here. Work can be set that the most able in the class can easily undertake and succeed in, but generally this will not support their intellectual development to the extent that they deserve and should be entitled to. Providing more challenging tasks for these students can be more educative, but at the cost that these students will likely need more teacher support – reducing the amount of time the teacher can spend with others in the class. We suspect this double-bind is in part why many gifted learners are not challenged sufficiently in their school science (Kerry & Kerry, 1997).

A PRAGMATIC NOTION OF GIFTEDNESS

As indicated above, the notion of meeting the needs of gifted students informing this chapter is not based on any suggestion that there are particular students who are inherently and permanently gifted and so always require distinct educational provision. Rather, it is assumed that in any class there will be a diversity of student characteristics, attainments, and potentials. A constructivist understanding of learning is that it is incremental, interpretive and so iterative (Taber, 2014), and consequently learning in science is highly contingent (Taber, 2009b). Undoubtedly genetic factors are *relevant* to how students in any class got to know and understand what they know and understand now. Family background will also have been relevant. So will all those learning experiences (within and outside school) prior to getting to this class. Some will have been taught by highly committed and skillful science teachers – others less so. Some will have particularly liked, or disliked, previous science teachers, which will likely have influenced their attitude to and engagement with the lessons. Some will have been strongly influenced – for better or worse – by peer groups in previous classes. And so forth. Whatever the reasons, whatever the particular contingencies, the students sitting in front of their teacher in any science class bring different intellectual skills, attitudes, confidence levels, self-beliefs, metacognitive strengths, study habits, prior knowledge, strengths within science, scientific interests, career aspirations, and so forth.

In just about any science class, in any school anywhere in the world, work that is set to be accessible to all class members will be of minimal educative value to some members of the class because although they can readily complete the work, they will learn little from it. This may seem less obvious if 'curriculum' is primarily understood in terms of content to be learnt – the gifted students can effectively learn the characteristics of the molluscs to add to their knowledge of the chordates; or effectively learn the properties of the group 5 elements to add to their knowledge of the group 7 elements. However, if our curriculum focus goes beyond knowledge 'acquisition' and sees knowledge construction to be as much about knowledge integration and creative application of knowledge, then simply knowing more facts is a useful but limited form of learning. Rather students have to be challenged to use what they are learning in ways that make the learning meaningful and personal. Too often students reduce learning science to being able to recall 'facts' and apply them (in formulaic ways they have also committed to memory) until they have taken the relevant examination. Too often students consider that is what the system is expecting them to do and indeed is set up to encourage them to do.

Where science learning is largely the temporary acquisition of relatively isolated propositional statements that could be readily accessed from the internet in a few seconds then there is little point in the exercise. Ideally the learning of 'facts' should be incidental to the developing understanding of theories and models – incidental, but likely to be more meaningful and long lasting because they are learnt within an authentic epistemological context. Of course many school students will need a lot of support in this kind of learning (Bloom, 1968), but needing support implies being challenged, and being challenged may be considered a prerequisite of a genuinely educative experience. This does not mean that every learning task should be so challenging as to puzzle (and potentially frustrate) the learner. There is certainly a need for consolidation of existing learning (Aufschnaiter & Rogge, 2012) although this should not be reduced to drill – but rather should better be experienced as fading of scaffolded support. However, all learners should regularly experience increments in the demand of different aspects of school science work to help them develop beyond current levels of competence.

Work that is designed to be challenging to the median achieving students in the class is however likely to lack any challenge for some of their peers (Gallagher et al, 1997; Winebrenner, 2000) – and so be unlikely to engage their concentration sufficiently to lead to a satisfying flow experience (Taber, 2015b). These are the students that we are referring to as 'gifted' in these science classes. Because of the highly contingent nature of learning, students who are gifted in the science class need not be those seen as gifted (in this sense) in other areas of the curriculum. Indeed the learner who is gifted in the physics class may not be in the biology class, and vice versa. Moreover, even within a single science subject, it will be inappropriate to consider that the gifted students are a fixed subset. For example, some students may find experimental design relatively easy, but find working with mathematical representations or creative writing in science more demanding. Realistically through, in any class, there are likely to be some students who would be considered gifted by our definition in most, if not all, lessons taught throughout the course, and so are in danger of spending the entire course rarely being asked to do anything where they are encouraged to go beyond familiar ways of thinking and working. Arguably these students are not having their educational needs met.

APPROACHES TO MEETING THE NEEDS OF THE GIFTED LEARNER IN SCIENCE

Traditionally there have been a number of approaches to meeting the needs of gifted learners for suitable educational provision. These include setting and streaming, acceleration and advancement, and enrichment. Each of these approaches has strengths, but also limitations.

Separate classes for the gifted?

Setting and streaming involve dividing up the students in an age cohort according to ability or prior attainment so that classes contain students of similar ability. This may be done across the curriculum (streaming) or within subjects (setting). One of the limitations here is that even if it is accepted that ability or prior attainment can be readily and accurately gauged such an approach can only divide a year group of students so far. In a school with four classes in a year group there can only be four streams or sets for example. If we assume that whatever we mean by ability is likely to follow something approaching a normal (i.e. Gaussian, so called bell-curve) type of distribution – as is commonly reported for 'IQ' scores for example – then the 'top' set or stream is still likely to contain students who are well into the tail of the distribution such that they are still substantially atypical of their classmates – something which may be less of a focus when classes are organised in terms of ability (Wilkinson & Penney, 2014). However, arguably, the teacher's task becomes more manageable if the most able students are at least working within the context of an 'above-average' cohort.

Whether prior attainment will also follow such a distribution (assuming it might hypothetically be possible to quantify it in a suitable way), is a moot point. If gifted learners have previously been set work that did not allow them to develop to their full potential it is quite likely that this distribution will have a somewhat stunted tail. This is also an area where inclusion of gifted learners links with inclusion concerns of other group of students (Anderson & Ward, 2014; García Franco, Verjovsky, Cisneros López, & de la Torre, Forthcoming; Gorard & See, 2009; Olszewski-Kubilius, 2011; Plucker, Burroughs, & Song, 2010; Rutkowski, Rutkowski, & Plucker, 2012). Where prejudicial views and expectations lead to assumptions about the potential of some groups of students – perhaps girls in some classes; perhaps working class black boys in some schools – then this can influence learning opportunities later leading to a greater disconnect between student potential and aptitude, and student prior achievement.

Where students have particular access barriers this can mask high potential. Learners from some indigenous communities may find aspects of school science strange and even unsettling (Jegede & Aikenhead, 1999). Students from some faith backgrounds may see aspects of school science at odds with their personal, community and family beliefs (Long, 2011; Taber, Billingsley, Riga, & Newdick, 2011), and this may lead to them engaging less in science than in some other subjects. Some students compartmentalise areas of their thinking such that apparent contradictions between scientific ideas and religious teaching are not an issue (Billingsley, Taber, Riga, & Newdick, 2013), but the potentially gifted learner is more likely to seek to integrate their thinking across diverse domains, making them more aware of the potential for apparent conflicts.

Students with some developmental disorders or some kids of disabilities may be 'twice exceptional' – having special support needs at both ends of the spectrum (Sumida, 2010; Winstanley, 2007). Students with behavioural issues may not demonstrate their true potential. Students working in a non-native language may not access teaching well enough to show what they can achieve. It is important not to overgeneralise here, students from some ethnic minorities may be 'over-represented' as high achievers in some educational contexts, and children who have a second family language other than the language of instruction may (assuming their competence levels are high enough in the language of instruction) actually outperform monolingual classmates. Individual learners have multiple identities and characteristics, and identifying learners with potential to be considered gifted in science should take into account how that potential is easily masked by issues of past access and equity. This is one strong reason for not considering judgements of giftedness – or not – in science as 'for once and all' evaluations.

Limitations of ability grouping approaches at the 'between-class' level include the difficulties associated with labelling and moving between streams or sets. Labelling (and it is difficult to stream or set without students being aware what the basis of grouping is) is well recognised as influencing outcomes through the expectations it produces in students and teachers (Rosenthal & Jacobson, 1970). In addition, once classes are working at a different pace or on different material it becomes difficult to promote students to a 'higher' group when this seems justified in terms of their current performance as they will be moved into a context where they lack the shared context and prior learning available to the rest of the class.

Setting and streaming are more justifiable if it is believed that:

- the basis of making judgements depends on an objective measurement;
- what is being differentiated (e.g. ability or prior attainment) is a uniform entity so people are being classed on some kind of single scale so there is minimal expectation that different students might qualify depending on the particular teaching and learning activity
- what is being differentiated (e.g. ability or prior attainment) is a fairly fixed quality so there is minimal expectation that a student's progression will be uneven to such an extent that their assignment to the most appropriate grouping will change

None of these assumptions seem especially sound. The first can be operationalised by using something like IQ as a proxy measure, as there are well developed measurement tools that give fairly stable scores for individuals (Matarazzo, Carmody & Jacobs, 1980), and which are well established as a reasonable predictor of general academic success (Sternberg, Grigorenko & Bundy, 2001). However, this is a very blunt tool in relation to potential and performance in specific subjects such as science subjects. The other two assumptions are even more questionable. Science and individual science subjects require a range of distinct qualities and skills, and learners may be 'gifted' in terms of some components and more typical (or possibly even below average) in others (Taber, 2015b). So the assignment to a distinct set or stream across science learning is not ideal. The notion of giftedness adopted in this chapter is more subtle – what is gifted is not the learner per se, but the learner in the context of particular learning requirements. The aim should be to seek to ensure that learners are always matched with learning demand in (particular) activities - not to class or label them in perpetuity. The assumption that a student who 'is' gifted will remain so, or that a student who is 'not' gifted cannot become so, ignores the individual variations between learners and is not in keeping with the constructivist perspective which sees the enablers and constraints on learning as a complex set of contingent factors which will be in flux and interact during learning (Taber, 2009b). These concerns may become more extreme when the 'gifted' are physically (and so somewhat socially) separated from the rest of the cohort to study in a different part of the school, or even a different institution altogether.

Moving the gifted through the system more quickly?

Acceleration (as the term suggests) seeks to increase the rate at which learners pass through the curriculum (Abeles, 1977; Ngoi & Vondracek, 2004). One approach to achieving that is advancing learners through the school system (Horsley & Moeed, Forthcoming). So students may skip a year (or more) and work with a year group that is older than them. In one sense grouping students by cognitive development level rather than chronological age makes sense as the basis of a schooling system. However when the school system is based primarily on age grouping (as in most national contexts), with just a small number of students advanced (or for that matter held back), cognitive development does not necessarily correlate to emotional and social development and advanced students may seem physically younger than their peers and may become socially isolated. Moreover, if skipping years means missing curriculum topics then cognitive development and subject knowledge may be misaligned in accelerated students compared with classmates.

However teachers may use modes of acceleration within classes, by making judgements that some students do not need to undertake introductory work that is important for most learners in the class – for example perhaps omitting time reviewing prior learning needed as a kind of scaffolding 'PLANK' (Taber, 2002) for most classmates - because they are ready to move on to more advanced material. The teacher then has a programme of learning activities (with associated learning goals) that are differentiated according to what she/he judges individual students are ready to move onto next. The most able students (as judged in the context of the particular topic and learning activities) will either skip or be given a shorter path through some of the activities others will complete, and so will progress to more advanced materials that others will not get onto. This is sometimes referred to as curriculum compacting (Riley, Bevan-Brown, Bicknell, Carroll-Lind, & Kearney, 2004), and is very much in the spirit of the kind of approach we recommend below. Curriculum compacting has been described as an essential strategy for teachers working with gifted learners (Renzulli, Smith & Reis, 1982). However, what is clear is that this type of teaching has potential to increase teacher workloads and requires a good knowledge of the students in the class and the ability to make, and sometimes modify during class sessions, decisions about the assignment of tasks to students and student groups, based on regularly reviewing progress being made.

The other problem with compacting curriculum in this way is that it needs to be coordinated across grade levels. There is little value in moving a more gifted learner on to more advanced work in one grade, if she/he is then asked to repeat it in a later grade level because it becomes standard fare for the older age group. Rather compacting either has to be planned across a school career (with the inherent problem that each iteration of meeting a topic is likely to accelerate the gifted learner further from the work being undertaken by most classmates, making designing episodes of whole class teaching increasing more problematic for the teacher) or the teacher needs to creatively find ways to introduce more advanced activities that will be genuinely educative without simply undermining later teaching. One possible focus here is making cross-curricular links – but this may only be highly effective when there is coordination across curriculum subjects to support the setting of authentic tasks that genuinely link teaching in different subjects.

One example of applying some of the idea described here was the use in a high school in Georgia, USA, or a bespoke two-year science and mathematics curriculum developed for students identified as gifted in those subjects (Tyler–Wood, Mortenson, Putney & Cass, 2000). This involved elements of curriculum acceleration and compaction introducing topics not normally studied by high school students, and with particular opportunities to link concepts met in science and mathematics. The innovation also involved extended laboratory

time and curriculum blocking (extended periods in the same subject) for classes, and was taught by 'superior' teachers. A team teaching approach was used, so that the mathematics teacher involved supported the science teachers in the science classes. It was reported that the teachers spent more than a thousand hours in preparing the new curriculum, and drew on over a hundred hours of consultation support during the first year of implementation. Whilst the outcomes were judged to be successful, it was recognised that such an approach could not readily be scaled-up across schools within normal resource allocations.

Offering the gifted something extra

Another common approach to meeting the needs of gifted learners is enrichment beyond the usual curriculum. The assumption here is that students follow the standard curriculum with their peers, but that this is enriched by additional educational experiences designed to supplement the standard fare (Abeles, 1977; Kulbago, Mulvey, & Alamri, Forthcoming; Oliver, Forthcoming). Enrichment of this kind may mean additional experiences outside lesson times, and possibly geographically outside school or temporally outside school terms (Stake & Mares, 2001). For example, school age students may attend science themed Summer schools, for example at universities during the long vacation (e.g., Stake & Mares, 2001), where they mix with students similarly identified as gifted. Such opportunities may have particular scientific themes, and may target particular groups of gifted students considered to be underrepresented in gifted programmes. As one example, the New Zealnad Marine Studies Centre has developed programmes of marine science for gifted school students, and has produced especially tailored versions of their programmes for groups of gifted Maori students (Rosin, Cutler & Carson, Forthcoming).

Enrichment is often enjoyed by students, especially where it allows them to meet like-minded others and work outside the normal constraints of the school classroom regime. For example, the authors were involved in offering an after school enrichment programme referred to as ASCEND – which stood for Able Scientists Collectively Experiencing New Demands (Taber, 2007b) – at the University Cambridge's Faculty of Education to 14-15 year-old students ('delegates') nominated by the teachers at local secondary schools. Delegates responded well to aspects of the initiative, and especially to being given extended time to work on tasks without constant overt monitoring and direction by staff (Taber & Riga, 2006). Other approaches to enrichment include after-school clubs and (sometimes residential) vacation schools.

Such an approach can be very valuable when it is considered that the standard school provision is insufficiently challenging the most able learners. However, this is a kind of 'patch' or 'make-do' rather than a genuine solution to meeting the needs of the gifted in science lessons. For one thing this kind of enrichment is designed to make up for students not being sufficiently stretched in school science – and the optional availability of such enrichment does not justify students having to experience core curriculum experiences that are not matched to their needs. Moreover as an add-on this kind of enrichment creates two problems. Firstly it relies on gifted learners, who may already be pretty frustrated in school science, volunteering to give up some of their own leisure time to attend programmes. Secondly it can be considered elitist as it provides experiences that are only made available to the most able students as if these learners should be provided with additional educational resource (rather than making sure that their fair share of educational resources is being targeted on provision which matches their needs).

There is certainly an important place for enrichment activities that allow learners to experience aspects of science not readily treated within the science curriculum (Chan et al.,

2010). But ideally such enrichment should be intended as genuinely enhancing suitable school provision, and available to all learners who are interested and feel they may benefit from it. For example, most of the activities that were the focus of the ASCEND project referred to above were focused on aspects of the Nature of Science that were not being explicitly engaged with in school classes (Taber, 2007b). These activities were designed to be challenging for the delegates by being content rich (i.e. requiring learners to do some editing and selection), loosely structured (compared with the familiar detailed step-by-step instructions the delegates tended to meet in school science tasks), and monitored with a hands-off approach (the teaching staff were asked to not intervene until students actively asked for help or were clearly not making any progress). Whilst Nature of Science activities do particularly lend themselves to matching the needs of the most able learners (Grevatt, Gilbert, & Newberry, 2007; Taber, 2007a, Forthcoming), it would have been possible to offer modified versions of these activities with other levels of structure, complexity and support. In a sense that process would be the opposite of what we are suggesting is needed in many classroom contexts. The ASCEND activities were pitched at a high level of demand, but could be reworked to suit less gifted learners: whereas in many science classrooms the activities are designed around the needs of the median learner with limited consideration of how to re-engineer them for the most able in the class.

Science teachers responding to diversity in their own classes

It may be sensible to acknowledge at this point that although there are classroom 'adaptions' that can be adopted to support gifted learners in the science class (Park & Oliver, 2009), there are sometimes considerable barriers to effectively responding to the challenge of meeting the needs of gifted students in science classes. Even when teachers are aware of the issues, and intend to differentiate their science teaching to provide for gifted learners, there may be a mismatch in practice (Coates, 2003). A major barrier is limited teacher time as preparation of lessons offering suitable differentiation for the full range of students present may require a good deal of work (Tyler-Wood, Mortenson, Putney & Cass, 2000), and in many school systems most teachers get limited time to prepare their teaching across a range of different classes. Some curriculum and assessment schemes may also seem to encourage teaching that covers content and helps students learn facts and algorithmic ways of applying them. Head teachers/principals, colleagues, school inspectors, parents and students all have expectations, sometimes quite fixed expectations, about what proper teaching should look like and what a productive class would present as. Even educational professionals have to overcome the widespread socialisation into a folk-theory (or alternative conceptual framework) of pedagogy that sees teaching as transfer of knowledge in which the students are largely passive receptors (Taber, 2013). The first author recalls a conversation with his headteacher when he was a new school teacher. The head came into the classroom to ask why the children were talking so much during lesson time. On explaining that the students were doing 'discussion work' the head responded by asking if they could do this without talking so much. Hopefully this particular anecdote would not be widely repeated in today's classrooms, but it brought home to the author just how strong some expectations of good teaching implying quiet classes listening to the teacher could be.

Many students acquiesce in a cultural norm that they will happily get on with work for most of the time in most lessons, as long as it is work that they can do without too much effort, and as long as they can keep up a whispered intermittent conversation with classmates about things that really interest them. After all, they are doing their work (usually seen as the work of getting things down in their notes, not expanding their conceptual frameworks), so there should be some give and take from the teacher. Teachers may even find that undermining such norms once they are well established is counterproductive and disruptive – at least in the short term. As suggested above, gifted learners may have come to associate their gifted status with an ability to successfully complete classwork quickly and accurately, such that it can be mentally ticked-off to move on the next task. They may see their task as analogous to the student who produces the page of clear script with no copying errors in perfect joinedup handwriting. The idea that a successful learning activity may actually imply false starts, wrong turnings, and even some frustration along the way to an intellectual epiphany, may simply be alien to their experience.

If school science suddenly shifts from being routine work to being difficult, hesitant, slow, messy etc., then there is a danger of students deciding they are not actually that good at science anymore and so should look elsewhere for subjects where they can readily achieve near perfection (in the set tasks). Clearly one imperative for schools should be to better inform students – including, but not just, the gifted ones – about the nature of learning and what they might expect to experience during the most useful learning activities. Many readers will have experienced students of moderate ability in classes who call the teacher the moment they get stuck because some question or instruction is not immediately clear to them. Whether this is seen as (i) laziness; (ii) habits of custom and practice; or simply (iii) the sensible adoption of what past school experience has demonstrated is an effective way of moving on quickly; is a moot point. If all students expected to have to struggle with work at times, and yet had confidence that they were often then likely to make progress with sufficient effort, then teachers might have more time for scaffolding genuinely challenging work for their students.

Differentiation by support when designing learning activities with the gifted students in mind

There are tools which can help teachers design learning activities which engage higher order cognitive demands (L.W.Anderson & Krathwohl, 2001; Kaplan & Manzone, Forthcoming; Taber & Corrie, 2007). This is important for *all* learners if they are to be supported in their intellectual development. As suggested above, a focus on the Nature of Science introduces some complexity that goes beyond the rhetoric of conclusions that typifies many textbook accounts of science. Asking students to engage with the arguments about how scientists should interpret and evaluate evidence in relation to competing theoretical frameworks offers a more authentic view of science (Romine & Sadler, Forthcoming) - but will be difficult for many learners. Engaging in genuine open-ended enquiry work (Grevatt et al., 2007; Heilbronner & Renzulli, Forthcoming; Taber & Cole, 2010; West, 2007) will similarly be threatening for some learners. Including socio-scientific questions in science classes questions that inherently do not have 'right' answers', but use scientific knowledge to inform decisions from different perspectives and value positions (Zeidler, Sadler, Simmons, & Howes, 2005) again offers potential for high level thinking (Levinson, 2007) and so also for class tasks being perceived as too difficult by many students. However, as was suggested with regard to the ASCEND project materials, what might be highly educative for all our learners is to plan for challenging, demanding learning activities - and then to consider how the teachers should provide differentiated support and scaffolding for those who will need it.

Differentiation by output rather than outcome

Another kind of differentiation that is sometimes referred to is differential by outcome – which in effect means having different expectations for different groups of students. Yet this could easily mean expecting some students to fail at most aspects of the set task! Setting thirty questions, and only expecting the gifted to get all of them completed is going to be disheartening for those students who know that the class will be moving on to the next task

without them having finished the work – yet again. However teachers may design learning activities that have different outcomes for different students. The gifted learners can be expected to produce a creative product – a brochure, a poster etc. – that goes beyond what others in the class are expected to do. Occasionally this might mean the gifted are working on a creative output whilst others are working through more routine exercises – but clearly that could seem like punishing the less able if it becomes a regular pattern. However, if all students were tasked with producing a brochure or poster, the more gifted learners could be asked to include links with other topics or curriculum subjects, or told that their product needs to be conceptualised from a particular perspective, or be designed to have a pedagogic purpose that supports other students (see more on this below). Gifted students can be asked to develop (rather than simply use) a new representational form, or to demonstrate a more multi-modal approach to their product.

A key issue we have not here given the attention it deserves is within-class grouping for activities. Gifted learners will sometimes benefit from being allowed to work alone, and to focus on their own thoughts without constant interruptions, although there are clearly social as well as pedagogic reasons to set many class tasks to pairs or groups of students. Similar ability grouping can be something gifted learners appreciate strongly, as it allows them to engage in discussion at a high level (Taber & Riga, 2007). Yet sometimes working in more heterogenous groupings allows them to take leadership and tutoring roles. This links the Vygotsky's ideas about the ZPD in that Vygotsky wrote of a learner being supported by an adult *or a more advanced peer* (Vygotsky, 1978). There is even a school of thought that peers are often able to engage with a learner's starting points more readily than an expert (i.e. a science teacher). Of course there is potential for students who misunderstand a concept or topic to then mislead others – but that can also occur with qualified teachers (Benny & Blonder, Forthcoming; Taber & Tan, 2011).

The important principle to adopt if considering peer tutoring within classes is that the tuition needs to be an educational experience for both parties: else there is danger of gifted learners being seen as 'free' teaching assistants who are asked to benefit their peers because 'they already know this' or 'they have finished their work already'. Peer tutoring as a learning experience is certainly a viable notion, as preparing for teaching can be a very good way of learning about a topic, that encourages deep engagement with the material to be taught (Taber, 2009a). Answering a struggling learner's questions – questions that often originate in a personal alternative take on a topic – can often test understanding much more than standard assessment questions formatted in familiar ways in formal examinations.

Bringing together several of the strategies discussed above, gifted students can be asked to work in groups to design teaching materials that could help others learn the material they have been studying. After getting the teacher to check for any obvious flaws, they could then be asked to evaluate their materials, with other students in the class helping them by acting as the learners, and then to make any necessary modifications and provide documentation that could inform a teacher or teaching assistant in using the materials in instruction. Alternatively they could be asked to design, and test and evaluate and modify, self-study materials that could be used by students who missed classes or would benefit from remedial provision. (In some cases the materials produced might well be of genuine value in working with future students, subject to the permission and acknowledgement of the instructional developers!)

In principle then, the model of a teacher working with thirty or so learners can be reconceptualised as a community of scholars with different levels of expertise, and different strengths and weaknesses, who are supporting each other as and when needed. To readers of a certain age this may have a ring of the type of progressive discourse about education common around the 1970s and which was largely later dismissed as too laissez-faire and idealistic. What we are suggesting here is certainly not that the teacher cedes their responsibility to direct teaching and learning, but rather that they construct a learning environment where learners are encouraged to support each other, and where being able to teach someone else about a scientific idea is recognised as a particularly valued form of evidence of successful learning.

The issue of how best to meet the needs of gifted learners in school science is one of international concern. That said, and despite a good many innovations and programmes designed to respond to the problem (such as the examples described above), there is limited research in science education exploring the issue to inform teachers in how to best identify and respond to the level of challenge that is needed in school tasks to make them genuinely educative for the most able learners. A research programme is clearly needed that moves beyond the level of general description in this chapter and which operationalises the principles in terms of exemplars that are useful to teachers (Taber, 2015b).

The present chapter has more modest aims. Here we have made the argument that gifted learners are readily excluded from a genuinely educative science education when the demands of learning activities are not sufficiently matched to their developmental needs – that is when activities are insufficiently challenging to move on their thinking or lead them to develop new skills or perspectives – rather than just 'acquire' more knowledge or practise well mastered skills within their zones of actual development. Giftedness is then a potential basis of exclusion from meaningful learning in its own right, as well as one that commonly interacts with a range of other inclusion issues – gender, ethnicity, language, physical and mental disabilities, faith background, etc.

This chapter acknowledges some of the possible limitations of the giftedness notion and the problems likely to arise with some common approaches to gifted provision. The chapter adopts a nuanced notion of giftedness (i) as always relative to some particular learning context; (ii) as open to degrees of giftedness; and (iii) as a judgement made at a particular time in relation to some particular educational episode rather than for all time. We argue for the need to design teaching activities that are found challenging by all the different students in a class, and suggest some approaches to going about this in terms of differentiation of support and expected outputs. Ultimately all students are entitled to school science provision that is genuinely educative, and yet too often the most able students in a class are finding school work to be routine and lacking any meaningful challenge. This situation has practical consequences – as gifted young people do not leave school as advanced in their scientific thinking and skills as they could, and often fail to consider science as likely to offer a satisfying basis for further study and a career – and fails to reflect the ethical imperative that requiring young people to attend compulsory schools should lead them to expect that their time and efforts there will be maximised for their benefit.

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