


Article

Biology Education: The Value of Taking Student Concerns Seriously

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Abstract: This article examines the question of how biology courses can take student concerns more seriously than they often do. The focus is on school biology although the arguments apply to other biology courses too. The article begins by examining Michael Young’s argument that schools should provide students with access to powerful knowledge—the sort of knowledge that they are unlikely to obtain from elsewhere—and compares this with John White’s argument that the curriculum should enable student flourishing, and that as part of this, there should be more student choice about what they study. It then discusses recent work on the benefits of independent research projects, in which students undertake authentic investigative work where they have considerable control over the work, and concludes that these generally motivate students and are a good source of learning for them. It goes on to examine what lessons might be learnt for school biology from the informal learning sector, such as Natural History Museums, where visitors have great autonomy with regard to what they study. Finally, it looks at the concept of ‘worldviews’ and argues that this provides another argument for taking student concerns seriously. The article concludes that taking student concerns seriously in school biology would facilitate human development, in particular, development towards greater student autonomy, and that this can be done in ways that have been tried and allow for high quality biology teaching and learning.

Keywords: biology education; student voice; independent research projects; informal science learning; autonomy; worldviews

1. Introduction

This article examines the question of how biology education courses can take student concerns more seriously than they often do. The focus is on school biology, although the arguments apply more broadly, for example to higher education. It is argued that most school biology education fails to take student concerns seriously enough and that if such concerns were taken more seriously a number of consequences would follow, in particular, greater student engagement with learning. This, in turn, would ultimately lead to greater student flourishing principally through having their autonomy respected more than would otherwise be the case.

While it may be that school biology takes into account student concerns to a lesser extent than school mathematics, chemistry and physics—perhaps because it is generally easier in biology than in these other subjects for a classroom teacher to take some account of the interests and dispositions of individual students – the standard current approach of school biology courses means that one of the consequences is that too many students who would otherwise be engaged by biology and might choose to study it once, when it is no longer compulsory, they lose interest in it and give it up as soon as they can. In fact, there are a range of arguments as to why student concerns should be taken more seriously, of which, this is only one. These various arguments are discussed throughout the article and then brought together in the Discussion in the context of considering what the purpose of teaching biology is.

The word ‘concerns’, as used here, encompasses a number of sub-meanings. The most straightforward is ‘interests’. It is well-established in the science education literature that increasing student interest benefits student engagement and learning [1–3]. A systematic review of the educational research literature on interest, motivation and attitudes towards science and technology at K-12 levels [4] found that much of the existing literature examined differences between boys and girls, even though such differences had quantitatively relatively small effects. The next most frequent area of study was the importance of teachers. Teachers who were enthusiastic, encouraging and close to their students had significant positive effects on interest, motivation and attitudes towards science and technology. Following teachers, the next most frequent area of study was collaborative work in class, followed by what was termed ‘meaningful learning’. The review also found that extracurricular activities, such as field trips, were successful in enhancing interest, motivation and attitudes, as were inquiry-based pedagogies. No attempt was made to consider in any detail why these various different approaches had the effects that they did.

Somewhat more fundamental than interests are ‘dispositions’. To have a disposition for something is to have a deep connection to it. For example, a person may enjoy listening to music and may even have had music lessons, but someone else brought up in a different family, where music was a central activity, is more likely to be disposed to music, to be passionate about it and to find meaning through it, whether by listening, playing or composing. There has been a small amount of work on whether changes in a biology curriculum can lead to changes in dispositions. One study found that the implementation of a novel curriculum that emphasised the use of published scientific data and media to learn about human impacts and ecological functions led to ninth-grade biology teachers being more disposed toward using data and media in their ecology and human impact lesson plans [5]. However, this is to use ‘dispositions’ to mean no more than ‘likely to’, whereas the word is generally held to mean something longer-lasting and more fundamental.

‘Engagement’ is related to both interests and dispositions—one is more likely to be engaged in something if one is interested in it or disposed towards it (‘disposed’ being understood in either its deeper or more superficial sense). Unsurprisingly, the literature on biology education and engagement therefore overlaps considerably with that on interest or motivation. In one study of student behavior on biology field trips, it was found that on-task behavior did not necessarily result in meaningful learning [6]. To be truly engaged with their learning, it was argued that students needed to engage in discursive argumentation, propose critiques, consider multiple perspectives and offer alternative ideas. However, this was less likely to happen when the student’s focus was on maintaining social harmony, which could all too easily be the case on a field trip where students typically work in self-selected groups.

More generally, engagement with school biology is likely to mean not only that students are more likely to choose to continue their studies in biology, but also that they are more likely to believe that they have a framework for understanding reality, to feel that the natural world is worth preserving and even that an understanding and appreciation of biology can help give them meaning in their lives. It is well established that such factors as childhood experiences in nature, enjoyment of solitary places, positive parental attitudes towards nature and the occurrence of others as role models all increase the likelihood that someone is engaged with the natural environment and disposed to protect it [7–9].

However, in response to the suggestion that we should ensure the biology curriculum is structured in such a way as to allow students to develop their interests in, dispositions towards and engagement with biology, it might immediately be objected that school students don’t know enough about biology to have their concerns about the content of what they are taught taken sufficiently seriously to determine the curriculum. What is better, this counter-argument would go, is for experts in biology education to ensure that students learn within the framework of a good biology curriculum, are well taught and fairly assessed. This can be done, in part, the counter-argument might continue, by ensuring that the curriculum does indeed contain those sorts of opportunities that the brief review indicates have positive results.

The line taken in this article is to begin by recognising that this argument between student concerns on the one hand and adult expertise on the other parallels some of the arguments that have been advanced by Michael Young on powerful knowledge in comparison with those of John White on student flourishing. These arguments are therefore examined. The article then goes on to build on this comparison by examining the literatures in a number of areas where there is evidence that students may respond positively, in a way that addresses their concerns about the biology curriculum, namely independent research projects, in which students have considerable autonomy about investigative work that they undertake; informal learning, which generally provides learners with more autonomy than they are able to exercise in school; and by having their worldviews taken seriously. It is concluded that taking student concerns seriously in school biology can facilitate human development, in particular, development towards greater student autonomy, and that this can be done in ways that allow for high quality biology teaching and learning.

The literatures are selected and analysed in different ways in the sections that follow. Section 2 examines the curriculum arguments of two leading theorists in the field of curriculum studies—Michael Young writing principally from a sociological perspective, and John White, writing principally from a philosophical perspective. In each case, a high proportion of their writings in the field of curriculum studies were read carefully. In addition, I have had a number of long discussions with each of them about their views, have attended seminars and lectures they have given, and have written with and on each of them. The intention, of course, has been to represent fairly their key points and then to relate these to the biology curriculum. Sections 3–5, on independent research projects, informal education and worldviews, respectively, are able to draw on more conventional literature reviews. In particular, I draw heavily in the section on independent research projects on a recent systematic review (the only one that has been undertaken). In the sections on informal education and worldviews, I draw on recent major reviews (albeit not systematic) as well as other literature in each field that is specific to biology education.

2. The Curriculum Arguments of Michael Young and John White

2.1. *The Curriculum Arguments of Michael Young*

Michael Young's recent arguments about the school curriculum have been coherently and powerfully expressed in a number of publications, of which perhaps the core text is his *Bringing Knowledge Back In* [10]. In this book, Young argues for a social realist approach to knowledge. Such an approach advances on two fronts: First, it is 'social' in that it takes seriously the fact that human knowledge is produced by groups of individuals; secondly, it is 'realist'. What Young means by this is that "A social theory must recognize that some knowledge is objective in ways that transcend the historical conditions of its production e.g., Euclid's geometry and Newton's physics" (p. 28). This social realist approach allows Young to reject both relativism and postmodernism, and also to avoid a naïve version of positivism.

A key conclusion that Young then reaches is that "The curriculum cannot be based on everyday practical experience. Such a curriculum would only recycle that experience" (p. 89). He also concludes that "It is important to be cautious about replacing a curriculum based on specialist research and pedagogic communities with one based on the immediate practical concerns of employers or general criteria for employability such as key skills" (p. 89).

Michael Young's ideas about the school curriculum have proved to be enormously fertile, leading him to develop and defend his views in numerous keynotes and debates and a range of publications. A convenient presentation of some of his most recent thinking is provided by his *Knowledge and the Future School*, co-authored with David Lambert and with inputs from Carolyn Roberts and Martin Richards [11]. In that book, Young is explicit that "the main function of school . . . is to enable all students to acquire knowledge that takes them beyond their experience" (p. 10). There is much in this short quotation that is notable; here, let me allow Young to elaborate on his use of 'all':

The school, for all its tendencies to reproduce the inequalities of an unequal society, is the only institution we have that can, at least in principle, provide every student with access to knowledge. The only alternative to schools for all is to accept that the majority will never have the educational opportunities that the minority has always treated as their right. We must respect and value the experience of pupils, but we can never allow them to depend on their experience alone. To do so would leave them (and us) in the position of our Stone Age ancestors, or worse; we would be no different from animals, who have only their experience (p. 13)

2.2. *The Curriculum Arguments of John White*

The sociologist Michael Young's ideas about what makes for a good curriculum can be contrasted with those of the philosopher John White [12]. In John White's first book, *Towards a Compulsory Curriculum* [13], White advanced a number of arguments that he then developed over many years. There is a central presumption that education must be for the benefit of individual learners and take them as its starting point:

It is at this point that notions of a 'child-centred' education and an 'integrated' education meet: The child must be at the centre of all he learns; education cannot be 'subject-centred' in this sense (p. 51)

White holds that education is about far more than the acquisition of knowledge about particular subjects. One point stressed in *Towards a Compulsory Curriculum* is that pupils "should finish their education with an understanding of the many different ways of life which they and others may pursue" (pp. 43–44).

A further development of what a school curriculum might look like if one were to begin with aims rather than subjects is presented in some of White's most recent writing, notably *An Aims-based Curriculum* [14]. The intention behind this publication was to provide a framework for the development of a coherent set of aims for the curriculum, some for implementation at national level, others at the level of each school. The argument begins with the premise that the aim of the school curriculum is two-fold: To enable each learner to lead a life that is personally flourishing; and to help others to do so, too. It is then argued that a central aim of a school should therefore be to prepare students for a life of autonomous, whole-hearted and successful engagement in worthwhile relationships, activities and experiences. This aim involves acquainting students with a wide range of possible options from which to choose, though it needs to be recognised that students vary in the extent to which they truly are able to make such 'choices'. With their development towards autonomous adulthood in mind, schools should provide students with increasing opportunities to decide between the pursuits that best suit them. Young children are likely to need greater guidance from their teachers, just as they do from their parents. Part of the function of schooling, and indeed parenting, is to prepare young people for the time when they will need to, and be able to, make decisions more independently. The arguments presented in *An Aims-based Curriculum* [14] are therefore, in part, ones about 'student voice'—giving students more say in the content of their education.

2.3. *The Contrasting Curriculum Arguments of Michael Young and John White*

Having introduced the curriculum arguments of Michael Young and John White, it can be seen that they represent two rather different views about the school curriculum. Fundamentally, Michael Young believes that schools should be in the business of providing students with access to powerful knowledge; such knowledge cannot be derived from students' everyday experiences. Rather, it resides in the accumulated wisdom of experts. By and large, therefore, too much student choice risks allowing students to spend their valuable school time on the sorts of activities that they have plenty of opportunity to spend their time on outside of school.

John White, on the other hand, sees school education as being all about enabling students to develop themselves and to flourish. Such flourishing entails giving students a considerable degree

of choice about how they spend their time in school. This is respectful of students, it helps promote autonomy, a key feature of what it is to be a fulfilled human being; it can motivate students and it takes account of the fact that students differ, so that the 'one-size-for-all' approach leaves many feeling that they and their schooling don't fit.

However, despite these contrasts, there are a number of similarities in the positions of Young and White in relation to the school curriculum [12]. In particular, both are deeply concerned with what the curriculum should be and with issues to do with social justice. Although neither focuses on issues to do with a shortage or unequal distribution of resources (such as the distribution of teacher excellence or finance among different schools), both are very concerned with the extent to which different students should all receive the same curriculum. It can be concluded that if applied inflexibly or naively Young's ideas could result in some students receiving an inappropriate education, one that would fail to engage them. Applied sensitively, they have the potential to complement the work of other educationalists, including John White, and enrich the education that schools provide.

Examination of the arguments of Michael Young and John White therefore suggests that there may be a balance that needs to be struck in terms of the amount of choice that students are given with respect to their school curricula. So, what might it mean in biology education for student concerns about their curricula to be taken more seriously and what evidence do we have that students themselves benefit when their concerns about their biology education are taken more seriously by those responsible for the biology curriculum? These questions are initially addressed by looking at the scope for the greater use of independent research projects, before going on to examine what can be learnt for biology education from the informal sector and from the literature on students' worldviews in biology.

3. The Benefits of Independent Research Projects

Independent research projects in biology are a particular instance of practical work. The nature and purpose of practical work in the teaching of school science has been widely explored and has generated an extensive literature (e.g., [15]). Practical work is seen as motivating for students [16], as part of the identity of science teachers [17] and as a way of developing conceptual understanding and certain skills [18,19]. Practical work in school science can take many forms: At one end of the spectrum is the 'recipe', in which students follow a prescribed set of actions that lead to a predictable outcome; at the other end is the independent research project, where students have a greater degree of control over the content of the practical work and the way in which the work is undertaken [20].

Recent years have seen the development of approaches such as authentic science, problem-based science and inquiry-based science, all of which seek to increase the amount of open-ended investigative work that students engage in, including work that takes the form of independent research projects. A recent systematic review of independent research projects [20] found that they are much more likely to be undertaken in biology than in chemistry or physics. One can only speculate on this. It may be that it is simply easier to find such projects in biology than in chemistry or physics—certainly, there is a long history in school biology of such projects being undertaken [21–23].

Almost all publications report benefits to participation in independent research projects. These benefits take a number of forms. Much of the work concentrated on impacts on students, and, in particular, their responses to participating in independent research projects, improvements to their learning, and their more general attitudes to science, including attitudes to pursuing a career in science. For example, the British Science Association [24], reporting on the CREST programme in the UK, found that the awards:

- are highly rated by students and teachers
- promote teamwork and creativity skills
- improve attitudes to STEM education and careers
- improve practical and technical skills and understanding
- are recognised as valuable by universities

- improve employability skills
- are equally attractive to both male and female students, and
- have higher than average take-up by students from lower socio-economic groups.

Schneider et al. [25], in the USA, reported that students who participated in independent research projects performed significantly higher on more than half the items on a national test of educational achievement of knowledge, skills and application than groups who traditionally did well on the test. They report that open-response items demonstrated enhancements in the quality of thinking among students who had undertaken independent research projects.

Relatively few negative consequences of independent research projects have been noted. Where these have been raised, they tend to focus on practical matters, such as the time-consuming nature of the work [26], including the negative impact on time available for completion and teaching of courses that are subject to external examination [27].

Group interviews with 39 young people aged 16–19 engaged in independent research project work showed that the projects gave them experience of thinking and acting like a researcher, and had positive impacts on their aspirations for future study of or employment in science [28]. Contrasting independent research projects with the practical work that was more common as part of their studies, students highlighted that they were looking in such projects to create new knowledge, where the answers were ‘not found at the back of the textbook’, for example:

There isn't necessarily an outcome that you're looking for, you're not told what to get like results that are consistent with something that's been done hundreds and hundreds of times. This is new, exciting stuff and you don't know what you're going to find.

We had to like read quite a lot of stuff on it because it goes beyond our syllabus, I'd say it helps our detail, like extract the more important knowledge . . . like because we've already [read] scientific papers from people like professors or biologists and that so . . . it helps understanding more advanced stuff.

It seems clear that there are a number of advantages to students engaging in independent research projects, provided that schools are able to manage these. The precise ways in which independent research projects are effective is more difficult to ascertain. For example, it could be because they give the students greater autonomy or because they provide them with real, open, relevant questions. Further work is needed to provide answers, though we should not expect that all students will benefit in the same way. Furthermore, there are, of course, other teaching strategies, such as inquiry-based science education and problem-based learning, that can provide students with some of the advantages afforded by independent research projects.

4. Lessons from Informal Education

The above conclusions from an examination of the research that has been undertaken on independent research projects indicate that taking student concerns seriously and giving them a degree of autonomy in at least some aspects of their biology learning can enhance both their learning in biology and their interest in it too. This parallels claims often made for so-called ‘informal science learning’.

Research in a number of countries has found mounting evidence that development of students' knowledge and understanding of scientific concepts takes place in a variety of settings—both in and out of school—and that such knowledge and understanding accumulate over time through exposure to a wide range of public resources, from museums to the media [29–32]. There has been controversy as to precisely what is meant by ‘informal science learning’; a useful definition of it is provided by Crane et al.: “Informal science learning refers to activities that occur outside the school setting, are not developed primarily for school use, are not developed to be part of an ongoing school curriculum, and are characterised as voluntary as opposed to mandatory participation as part of a credited school experience” [33] (p. 3).

Experiences with informal science learning can, for some, constitute their first real experience of science learning [31], and such experiences can play a key role in the development of skills, dispositions, practices and knowledge in helping students to learn about science [34]. Clear evidence for this comes, for example, from the US National Research Council report *Learning Science in Informal Environments* [31]. This report indicates that community institutions (such as museums and zoos) that support science learning are able to support young people's learning of and interest in science better than schools working in isolation from such organisations. Braund and Reiss [35] recommended that students should be presented with opportunities for engaging with informal science learning environments and have opportunities to visit zoos, science centres, museums and botanical gardens. Data from international tests such as the Programme for International Student Assessment (PISA) show that informal science learning experiences are positively associated with interest and achievement in science [36].

Mujtaba and colleagues [37] have examined the potential for Natural History Museums to enable student learning and interest in biology. A common claim for museums in general and Natural History Museums in particular is that they are very successful at engaging visitors. Several research studies indicate that visitors to informal learning environments, including Natural History Museums, greatly appreciate both the entertainment and the social aspects of their visits alongside the opportunity for learning. Intrinsic reasons (such as enjoyment) are one of the key reasons why people visit informal learning environments. The challenges incorporated into interactive or other engaging exhibits can elicit feelings of positive engagement [38] and even after the visit has ended, people may continue to express interest and excitement about what they have learnt [39], particularly when they have increased their skills and knowledge [40].

Given that Natural History Museums invest significant resources in attempting to engage school students, the affective value of visits to them has received surprisingly limited research attention. The term 'affective learning' has been defined as meaning the changes in visitors' attitudes and the emotions that are created by the learning that takes place at informal science learning institutions [41]. Affective measures (interest, enjoyment, motivation and career aspirations) have been reported to be positively impacted by interactions with museum or science centre exhibits. For example, when Heureka, a Finnish science centre, created opportunities for students to engage in the open-learning environments of the centre, students' intrinsic motivation was increased [42]. It needs to be admitted that Heureka is not a typical science centre, and nor is the San Francisco Exploratorium which is mentioned in the next paragraph. However, the above reviews [31,37] examined a considerable number of sites of informal learning and found a range of benefits to learning. Furthermore, a survey of 1019 undergraduate students at the University of Helsinki showed that informal science education institutions had a strong impact on the academic career choices of students [42]. This finding mirrors the PISA reports, referred to above, of association between informal science learning experiences and interest in science as a career [36].

The educational value of trips to museums and afterschool programmes at museums has been reported as being reflected in an increase in students' performance in school science as well the development of more positive attitudes towards science careers, and an increase in interest and self-confidence [43,44]. For example, the Evolutions Afterschool Program at the Yale Peabody Museum of Natural History has shown consistently positive impacts on its participants and their interest in and attitudes toward science. Students' increased school success and enhanced intrinsic motivation in the San Francisco Exploratorium's programmes is related to the programme's goals of fostering students' autonomy and providing an atmosphere of responsibility and respect [45]. However, it is difficult to identify precisely what it is about informal learning sites that makes them popular and helps enhance learning, since they differ from formal sites of learning in a number of ways (voluntary/involuntary access, degree of autonomy once there, presence/absence of formal testing, nature, quality and authenticity of the resources, expertise of the 'teaching' staff, etc) that are very difficult to disentangle.

5. Worldviews and Biology Education

A rather different argument for taking student concerns seriously comes from thinking about the importance of worldviews for biology education [46]. In *World Views: From fragmentation to integration*, Diederik Aerts et al. (1994) stated that “A world view is a coherent collection of concepts and theorems that must allow us to construct a global image of the world, and in this way to understand as many elements of our experience as possible” [47] (p. 17). In a frequently paper, Bill Cobern [48] pointed out that science educators generally assume that if students can see that scientifically orthodox conceptions are more intelligible, plausible and fruitful than other conceptions, they will come to accept these scientific conceptions. Cobern described this as a ‘rationalistic view’. He went on to point out that the notion of worldviews provides a different way of understanding why people hold the views that they do.

In science education, the notion of worldviews is increasingly being employed. For example, in an edited volume of papers from the journal *Science & Education*, titled *Science, Worldviews and Education* [49], a number of philosophers, scientists and science educators use the thinking behind worldviews to explore a range of issues including whether science itself is a worldview and whether science can test beliefs in the supernatural. The term has recently been explored as a way of helping conceptualise why, despite the best efforts of many science educators, so few students leave their schooling with the sort of scientific understanding and disposition that most science teachers wish they had. The principal conclusion is that school science fails to enable most students to see the world from a scientific perspective [50]. By and large, students are content to see the world much as they always have.

At its simplest, a worldview is a reasonably coherent way of understanding (‘viewing’) reality (‘the world’). In science education, the term has been most extensively used in the context of evolution where creationists can be said to hold a particular version of a religious worldview (a creationist worldview) that sits in opposition to the standard scientific understanding. One of the key points about worldviews is that it can be difficult for someone who has never inhabited a particular worldview to imagine what it is really like to do so. In Christianity, a creationist is likely to think that the world will soon be coming to an end, very possibly in their lifetime, that there is a world to come and that the eternal fate of each and every one of us in that world depends on whether or not in this world we accept the teachings of scripture. As has been argued elsewhere [50], if one is not a creationist and wants to get more of an idea as to how many creationists see the world, one can try reading some of the 16 best-selling religious novels by Tim LaHaye and Jerry B. Jenkins that constitute the ‘Left Behind’ series (e.g., Reference [51]).

It can be useful to biology educators to envisage contexts other than evolution where the notion of worldviews may be employed. Climate change is an obvious possibility—but consider vaccination.

Vaccination

Vaccination is frequently presented in school biology textbooks as an unproblematic success story. After an account of Edward Jenner’s iconic 1796 experiment on 8-year-old Edward Phipps (sometimes with a nod to Lady Mary Wortley Montagu’s earlier introduction of the Ottoman practice of ‘variolation’—inoculation against smallpox—on her return from Turkey), graphs are presented showing dramatic decreases as the result of inoculation in the incidence of such diseases as smallpox and polio.

However, not everyone is enthusiastic about vaccination. Objections began almost as soon as the practice was introduced. Nineteenth century objections included arguments that vaccinations frequently didn’t work and were unsafe [52], or that their compulsory introduction (e.g., the 1853 Compulsory Vaccination Act in the UK) violated personal liberties [53]. To this day, objections to vaccinations exist for a number of reasons. In addition, still, to concerns about safety or the over-ruling of individual liberties, a distinctive issue about vaccinations is that the benefits from them can be obtained by individuals who have not been vaccinated providing enough other individuals have been. Parents who refuse to have their children vaccinated are, therefore, sometimes accused of selfishness.

From the perspective of biology education, the important point is that objections to vaccinations may not result from misconceptions, as these are typically understood in the biology education

literature—e.g., that plants do not respire during the daytime—but from deeply held views to do with the right of the individual to make choices for themselves and with the limits of state authority.

We do not yet have a literature in science education that advises how the biology of vaccinations might better be taught to those who have these sorts of fundamental objections. However, there is a growing literature about how evolution can profitably be taught to those who reject it for reasons to do with worldviews, specifically issues connected to religious faith. Research suggests that careful and respectful teaching about evolution can make students who initially reject the theory of evolution considerably more likely to accept at least some aspects of it. Winslow et al. [54] studied 15 biology-related majors or recent biology-related graduates at a mid-western Christian liberal arts university in the USA. The data were interviews, course documents, and observations of classes (in a course called 'Origins'). The study found that most participants were raised by their families to believe in creationism, but came to accept evolution through evaluating the evidence of it, negotiating the meanings of Genesis, recognizing evolution as a non-salvation issue, and observing the teachers as Christian role models who accept evolution. For example, one student reported:

They can say they're Christian and be an evolutionist, but it would really help for Dr. [professor who taught the course] because she actually showed you. She'd talk about God and . . . then she also talked about evolution and so you kinda had to reconcile the two . . . My whole life it was just two things that were separate and they must stay separate, but with her they kinda came together and you had to reconcile them (p. 1036)

This quotation indicates the value of teachers taking serious account of student concerns.

6. Discussion

This article has presented an argument that student concerns should be taken more seriously in school biology. By examining the literatures on independent research projects, informal learning and worldviews in biology education in the light of the on-going debate between Michael Young and John White about how curricula might best be designed, it provides answers to the question of how biology courses can take student's concerns more seriously than they often do. It is anticipated that benefits should include improved student learning and greater engagement with biology, resulting in more students studying the subject once they are no longer required to at school.

Since time immemorial, it has been presumed that at least one important component of what it is to be human is to be able to make choices. Formalised by Kant in his Categorical Imperative, the notion of autonomy as perhaps the foundation stone of personhood has been, broadly speaking, accepted ever since. The concept is widely recognised within medical ethics and in such historical formulations as the US Declaration of Independence—'We hold these truths to be self-evident'—and the cry of the 1789 French Revolution: '*Liberté, égalité, fraternité*'. It finds more recent development and amplification in the works of the existentialists including Satre, Heidegger and Camus.

For the purposes of biology education, there are a number of reasons as to why students' concerns might be taken more seriously; which of these one considers most important will depend on one's views as to the reason for having biology education [55–58]. One reason is to reduce the drain of students, who become disengaged with much of school biology and leave as soon as it is no longer compulsory. More fundamental arguments are to do with the ultimate aims of education; a good biology education—one that is respectful of students and pays due attention to their desires and interests—can promote student autonomy, contributing to self-development and student flourishing.

Children develop autonomy as they age. An important decision, therefore, for those with the job of looking after children, whether parents, teachers or others, is how to help those in their charge to develop autonomy as they develop. The contention of this article is that biology education can too often underestimate what young people are capable of. We can have biology curricula that encourage students to learn powerful knowledge and we can have the same curricula, with associated pedagogies and assessment instruments, that allow students to make choices and to be rewarded appropriately for

making these. By so doing, we can have biology classrooms that are more respectful of students and more engaging for them too.

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