The Contribution of Socioscientific Issues to Science Education: A UK perspective

Alex Jeffries

Amanda McCrory

Michael J. Reiss

Abstract

There are a number of arguments in favour of the greater inclusion of SSI in science education. In particular, SSI can be motivating for learners, give them a deeper understanding of how science is interdisciplinary, and help them appreciate the complexities of applying the science learnt in classrooms and labs to the real world. In the UK, though, SSI are under-used in science education, whether at primary, secondary or tertiary level. We examine the reasons for this by looking at the utility of SSI from a range of perspectives – including Stoicism and neoliberal understandings of education. A crucial aspect of Stoic philosophy, particularly relevant to SSI, is the Stoic view of physics as a necessary foundation or precursor for ethics. They believed that making informed ethical decisions required a deep understanding of the world in which these ethics were applied. This is because ethical principles are anchored in value judgments about what is significant and meaningful, but confined within the realm of what is realistically achievable. Since the 1980s, neoliberalism has increasingly been the dominant ideology shaping school and higher education policy in the UK, maintaining that the education system should be managed according to the principles of a free market. We examine both Stoicism and criticisms of a neoliberal approach to school education and discuss how SSI might be used to contribute to the formation of scientific literacy, epistemic insight and human flourishing at all three levels of formal education.

Introduction

There are a number of arguments in favor of a greater inclusion of socioscientific issues (SSI) in science education. In particular, such issues can be motivating for learners, give them deeper understanding of how science is interdisciplinary, and help them appreciate the complexities of applying the science learnt in classrooms and labs to the real world. In the UK though, SSI are under-used in science education, whether at primary, secondary, or tertiary level. This chapter looks at the utility of SSI from a range of perspectives and examines the reasons why SSI are not used more widely in science education, with a particular focus on neoliberal understandings of education that are increasingly prevalent. We discuss how SSI might be used to contribute to the formation of scientific literacy, epistemic insight and human flourishing at all three levels of formal education. We begin with an unusual argument as to the value of SSI, namely one derived from Stoicism.

Jeffries, A. C., McCrory, A. & Reiss, M. J. (2024) The contribution of socioscientific issues to science education: A United Kingdom perspective. In: *A Moral Inquiry into Epistemic Insights in Science Education: Personal and Global Perspectives of Socioscientific Issues*, Zeidler, D. L. (Ed.), Springer, Cham, pp. 387-408. https://doi.org/10.1007/978-3-031-63382-9_20.

Stoicism and SSI

Most people know of Stoicism only through the injunction ‘to be stoical’, meaning that one should endure hardship without showing one’s feelings or complaining. Somewhat unexpectedly, there has recently been an upsurge of influencers on TikTok, Instagram, YouTube and other platforms enjoining us to draw on Stoic philosophy to overcome destructive emotions. This sudden popularity has surprised philosophers, and it has been pointed out that these short videos and the general recent enthusiastic advocacy of Stoicism, promising us productivity and happiness, ignore its full scope and underpinnings, in particular its relationship to science (e.g., Duncombe, 2023).

The philosophy of the ancient Stoics is best known today for its focus on practical ethics. However, historically it was grounded in a tripartite framework, prioritizing logic, physics, and ethics, in that order. Logic, for the Stoics, was foundational, serving as a tool for reasoning and rationality and therefore the discernment of truth and fallacy. ‘Physics’, in Stoic philosophy, was a much broader concept than the word represents today. For the Stoics, physics encompassed not just the workings of the natural world, but also metaphysical elements, psychology, and even theology (Menn, 1997). Ethics, forming the third part of this framework, provided normative principles and practical guidance to achieve and sustain *eudaimonia*, a state of flourishing or well-being. For a comprehensive review of ancient Stoic history and philosophy, see Sellars (2006).

A crucial aspect of Stoic philosophy, particularly relevant to SSI, is the Stoic view of physics as a necessary foundation or precursor for ethics. They believed that making informed ethical decisions required a deep understanding of the world in which these ethics were applied. This is because ethical principles are anchored in value judgments about what is significant and meaningful, but confined within the realm of what is realistically achievable. The practice of making normative propositions and assigning values in human behavior and psychology are an integral part of this process and cannot be known *a priori* but require knowledge of the natural world by a suitably literate society.

While the fundamental nature of the human mind remains consistent from ancient times to the present, the practices and contexts of the modern world are heavily influenced by scientific and technological developments and so differ from those of our Stoic predecessors in many significant ways. These differences manifest in new possibilities and concerns, especially in fields that are influenced by scientific knowledge and understanding. Though ancient philosophy laid the groundwork for principles of argumentation and reasoning, there have been significant developments since, particularly in probabilistic and statistical thinking, largely spurred by the development of scientific and mathematical knowledge. But despite the huge advances in the volume and complexity of our knowledge and understanding, the basic Stoic perspective of physics informing ethics is still a valid one. Perhaps even more so today, ethical judgements need to be informed by scientific realities, which requires a scientifically literate society.

The aims of the UK education system

In the modern world, secular education has become a nearly ubiquitously practiced system in many countries for the structured transmission of knowledge, skills, values, and beliefs from one generation to another. It is largely the vehicle for developing a scientifically literate society. The United Kingdom (UK), as one would expect from its being a democratic, industrially developed country with a relatively high standard of living and technological infrastructure, has a well-established, diverse, and (to some extent) decentralized education system that ranges from early years through to tertiary level.

The aim of this system is to 'produce' citizens who can engage in a diverse range of activities that ultimately help towards the maintenance and enhancement of society's wellbeing. The potential activities that could contribute is vast, and extremely difficult to rank by order of impact. However, for better or worse, the primary aim of the UK education system is the generation of productive and constructive citizens who can contribute, directly or indirectly to the country's economic growth. It is largely to this end that science education is directed, and the concept of a 'physics'- guided ethical society is either completely unacknowledged or at best peripherally alluded to. For example, the UK government's latest policy statement on the future of science and technology speaks almost entirely to economic impact, with just a nod towards human health and sustainability, and never mentions wider societal concerns such as ethics, or character development (Department for Science, Innovation & Technology and Prime Minister's Office, 2024). Similarly, policy advisories on education's contributions focus on economics (e.g., Grant, 2017). In an occasional exception, Power et al. (2015), in a non-governmental policy advice initiative by the Health & Education Advice & Resource Team (HEART), draw attention in an annex to Unesco's 1998 *World Declaration on Higher Education for the Twenty-first Century: Vision and Action*, but do not discuss it.

Tertiary education

The tertiary education system in the UK is decentralized in terms of not having a truly universal curriculum and institutions having considerable scope for autonomy, albeit less now than in the past as successive governments have exercised greater control. University status is granted through a rigorous process *via* either royal charter, Orders of Council, and/or other approvals under the Further and Higher Education Act 1992 (The National Archives, 2024). Each of these approaches require the submission, scrutiny, and approval of documents that outline aspects such as the institution's powers, internal governance structure and regulations, purpose, and charitable status, and are judged on criteria such as academic quality, financial sustainability, and public benefit. The public benefit criterion is usually generic, but a central role is typically now given to the economic concept of return on investment for graduates and society. Overall, the university creation process provides high level oversight of the number and quality of higher education institutions (HEIs) in the country and details of an HEI's remit is largely left to the individual institutions.

Universities, once created, develop their teaching program portfolios, faculty, and infrastructure with a large degree of autonomy. Curricula are not set out directly by a central authority but are monitored by an independent body, the Quality Assurance Agency for Higher Education (QAA; https://www.qaa.ac.uk/). The QAA monitors and advises on the standards and quality of UK HEIs through periodic inspections of institutions and reporting of its findings and recommendations to those institutions, in addition to providing

Jeffries, A. C., McCrory, A. & Reiss, M. J. (2024) The contribution of socioscientific issues to science education: A United Kingdom perspective. In: *A Moral Inquiry into Epistemic Insights in Science Education: Personal and Global Perspectives of Socioscientific Issues*, Zeidler, D. L. (Ed.), Springer, Cham, pp. 387-408. https://doi.org/10.1007/978-3-031-63382-9_20.

overarching advice to various concerned government bodies about the whole UK higher education sector. In addition, the QAA develops and maintains the UK Quality Code for Higher Education which sets out the expectations for HEIs. Key components of this are a set of Subject Benchmarks that specify the expected standards of graduates from various subject degrees (QAA, 2024). At the time of writing there are 28 Subject Benchmarks developed, of which arguably 19 are within the 'science' umbrella. None of the QAA's outputs have statutory or regulatory authority; instead the system relies on self-regulation within UK universities (statutory powers over HEIs are held by the Office for Students (OfS), established in 2018; https://www.officeforstudents.org.uk/). Nevertheless, UK HEIs take QAA inspections and recommendations very seriously and the Subject Benchmark Statements are typically consulted during the design and development of new courses.

As an example, the Subject Benchmark Statement for Biosciences (QAA, 2023) makes no mention of morals, or character development. It does however concern itself with ethics from a range of perspectives, though mainly focused on professional practice (such as scientific integrity), the use of humans and other animals in research, sustainability, and associated legislative and regulatory frameworks. Section 1.14, within a wider equity, diversity and inclusion section, suggests that the historical role of biological science in social injustice could be critically explored as part of a program. Similarly, both historical and current ethical issues and perspectives in the practice of science are suggested as exploratory topics, and from a perspective ranging from the individual student through to the whole of society. Section 1.15 suggests that individual students explore the biosciences from a perspective of their personal and cultural backgrounds, hinting at moral or ethical self-development, but an explicit justification for this perspectival approach is not given. The section concludes with a succinct steer for curriculum development of, stating "Curricula should facilitate the development of culturally aware graduates, with ethical and open approaches to thinking and practising the Biosciences." (QAA, 2023, 5). Each Subject Benchmark Statement is specific to its discipline in terms of its coverage and the Statements vary in their formats and extent. For instance, the Subject Benchmark Statement for Physics, Astronomy and Astrophysics (QAA, 2019) is much shorter than the one for Biosciences and makes only two bullet-point references to ethics, and only in the context of "professional behaviour."

The biological sciences contain within them numerous issues, past and present, that have direct ethical implications, perhaps more so than any other scientific discipline. These range from historical topics, such as eugenics, through to current technologies, such as genetically modified organisms, cloning, assisted reproductive technologies, and the ownership of biological sequence data (e.g., Miller & Selgelid, 2007). All are examples of contentious, often ill-structured ('wicked') topics with significant societal impacts; they require sophisticated scientific knowledge and evidence-based reasoning to fully comprehend and evaluate. This makes them ripe for SSI-based teaching and learning, and the combination of reasoning, science and ethics illustrates that a Stoic approach, whether explicitly acknowledged as such or not, not only has merit but is essential.

As the biological sciences often raise ethical questions, it is not uncommon to find a biological ethics module offered to students on programs across the biological sciences subdisciplines and there now exist a number of textbooks to help bioscience students to reason ethically about their subject (e.g., Bryant & la Velle, 2018). A full module in this area is typically an optional choice for students, but some addressing of professional practice (e.g., scientific integrity, plagiarism, etc.) will likely be a mandatory component of key skills

Jeffries, A. C., McCrory, A. & Reiss, M. J. (2024) The contribution of socioscientific issues to science education: A United Kingdom perspective. In: *A Moral Inquiry into Epistemic Insights in Science Education: Personal and Global Perspectives of Socioscientific Issues*, Zeidler, D. L. (Ed.), Springer, Cham, pp. 387-408. https://doi.org/10.1007/978-3-031-63382-9_20.

training. As with the Subject Benchmark Statement for Biosciences, the focus of such teaching will largely be on professional practice and the ethical implications of technologies and ethical approval frameworks. A more introspective approach to personal moral/ethical/character development will most likely be a byproduct of this teaching rather than an explicitly taught and/or facilitated educational experience.

Another influence on curriculum design and implementation in UK HEIs, and common worldwide, comes from external program accreditation organizations. Certain degrees are required to meet industry or professional standards and use independent verification of curricula, faculty expertise, teaching facilities and graduate outcomes to regulate subsequent registration and employment of graduates. For instance, the General Pharmaceutical Council (GPhC) and the General Medical Council (GMC) rigorously control pharmacists, and medical doctors, respectively. These accreditations have statutory status. For example, the Pharmacy Order 2012 mandated the GPhC accreditation for pharmacists and pharmacy technicians to practice, whilst the Medical Act 1983 established the GMC as the independent regulator of medical practice.

In addition to these statutory accreditation organizations, a number of non-professional and non-statutory accreditation organizations also exist for various disciplines and have a similar influence on curriculum development and teaching practice. For instance, the Royal Society of Biology (RSB; https://www.rsb.org.uk/) exists to quality assure the curricula, faculty competence and graduate attainment for a range of biosciences programs at UK HEIs, from the undergraduate to doctoral level. Such accreditation is voluntary for the institution but is typically sought to help with employability of graduates, the fostering of industry contacts, and recruitment of students.

Similar to the Subject Benchmark Statement for Biosciences discussed above, the RSB's Accreditation Handbook (RSB, 2023), which lays out the details of its accreditation process, makes no mention of morals, moral character or development, or personal character development in general. However, it does make mention of ethics in multiple places but mostly in a generic manner and again with an emphasis on professional practice. It briefly recognizes that the teaching of ethics will provide learning outcomes consistent with those of SSI. For example, it states that, "The study of ethics helps students to develop widely applicable skills in communication, reasoning and reflection, as well as an introduction to codes of conduct and work as a professional scientist." (RSB, 2023, 23). The Accreditation Handbook further advises that "Regulatory and ethical issues, including environmental and social aspects, are considered and addressed by students at appropriate times throughout their programme of study." (RSB, 2023, 29).

Within the RSB Accreditation Handbook, the strongest statement that aligns with the ethos of SSI are guidelines for the "Development of creativity and innovation relevant to the work place" (RSB, 2023, 26). This section advises that, "Institutions should provide evidence that they encourage students to be creative by 'thinking differently." (RSB, 2023, 26). It further details that "Students should be encouraged to: be inquisitive and open-minded; welcome the unexpected; challenge assumptions and (from time-to-time) defy convention; think beyond their own discipline and make interdisciplinary connections; and consider problems from the perspective of non-biologists." (RSB, 2023, 26). The Accreditation Handbook also gives some general advice about teaching and assessment in this domain:

Jeffries, A. C., McCrory, A. & Reiss, M. J. (2024) The contribution of socioscientific issues to science education: A United Kingdom perspective. In: *A Moral Inquiry into Epistemic Insights in Science Education: Personal and Global Perspectives of Socioscientific Issues*, Zeidler, D. L. (Ed.), Springer, Cham, pp. 387-408. https://doi.org/10.1007/978-3-031-63382-9_20.

> HEIs should make it clear how they promote creativity and creative problem solving, using techniques designed to develop individual and group creativity. For group sessions there should be evidence that institutions offer structured, constructive and inclusive approaches to creative problem solving. Where these activities are assessed, emphasis should be placed on students demonstrating how they have engaged with techniques designed to promote creativity in individuals, and the extent of their participation in group sessions. As an example for the former, students could be asked how they have utilized a specific technique during creative problem solving. Students should not be awarded marks solely on the basis of coming up with novel ideas, as this is frequently an unrealistic expectation. (RSB, 2023, 26)

Such guidance facilitates teaching and learning about SSI. However, while UK tertiary bioscience courses do often include a certain amount of ethics, they are less likely to draw on other non-science disciplines. History is likely to be used simply to contextualize (e.g., Darwin when teaching evolution, Mendel when teaching genetics – and that less now than was the case) and, in our experience, some disciplines – e.g., politics, economics and sociology – seem rarely to feature, though we are unaware of any systematic research on this issue.

In conclusion, although an explicit articulation of SSI principles is absent in the various guidelines and oversight mechanisms governing UK HEIs by both governmental and independent entities, the ethos of SSI is evident in instances pertaining to ethical considerations and student skills such as creativity and problem-solving. The UK HEI pedagogic culture is quite uniform which facilitates the dissemination and integration of SSI-related principles implicit in the above-mentioned sources, with adjustments made to accommodate the distinctive requirements of each academic discipline. However, as discussed above, the predominant focus is on fostering professional practice, upholding scientific integrity, and adhering to pertinent legal frameworks and monitoring mechanisms. Within the realm of the sciences in higher education, the incorporation of extended moral or personal ethical development, as well as broader character development, seems to be significantly scarcer. The curricula for scientific disciplines typically allocate minimal time for such pursuits, with faculty members generally, in our experience, exhibiting a limited inclination and proficiency for facilitating in-depth exploration of moral or personal ethical dimensions. The emphasis in character development within the sciences, when there is any, predominantly revolves around cultivating traits such as originality, curiosity, creativity, personal responsibility, conscientiousness, and tenacity, and all within the context of carrying out scientific research. This gap is a potential opportunity for more explicit SSI approaches to teaching at HEIs as it pertains to moral and character development. However, this will face the challenges of forming a coherent justification for the value of such teaching and the formation of advocacy and dissemination that would be needed to generate what is, in essence, a cultural change. Arguably, the vehicles best suited to initiate this would seem to be the governmental and independent entities that in their own ways have been influencing the development of program content and structures at UK HEIs over many years. Otherwise, the inclusion of SSI in UK HEIs is likely to depend on local enthusiasms, leading to, at best, a patchwork coverage.

School education

Jeffries, A. C., McCrory, A. & Reiss, M. J. (2024) The contribution of socioscientific issues to science education: A United Kingdom perspective. In: *A Moral Inquiry into Epistemic Insights in Science Education: Personal and Global Perspectives of Socioscientific Issues*, Zeidler, D. L. (Ed.), Springer, Cham, pp. 387-408. https://doi.org/10.1007/978-3-031-63382-9_20.

To a greater extent than at tertiary level, primary and secondary school education depends on which of four UK nations (England, Northern Ireland, Scotland, Wales) one is talking about. Scotland, in particular, has an education system that is, and has long been, very different in structure and curriculum from that of the other three UK nations.

In England, Northern Ireland and Wales, a particularly important date for science education was the introduction, in 1989, of the National Curriculum. Initially, this applied to all state schools, with only the 7% or so of students in independent (fee-paying) schools exempt. However, the reality has been that the examinations sat at age 16 (GCSEs, General Certificates of Secondary Education), normally after two years of study, need to be aligned with the requirements of the National Curriculum. As a result, the various subject curricula taught to 14-16 year-olds in state and independent schools are very similar, and this has had a certain amount of 'washback', so that the similarities at early ages are greater than might have been expected.

The UK school education system is generally held to be one of the most complicated to explain, not just because of the differences between the four UK nations but because of the existence not only of a state and independent system but also of a plethora of types of school within the state system. For example, academies were introduced by the Labour government in 2002 and free schools by the Conservative-Liberal Democrat coalition following the 2010 general election. The relevance of this is that both academies and free schools are not obliged to follow the National Curriculum. Indeed, now that the majority of state schools are academies or free schools, it might be thought that government control over what is taught in school has weakened. In reality, partly because of GCSEs, as mentioned above, and other elements of the examination system, this has not proved to be the case.

Another important lever controlling what is taught in schools is the inspection regime. This occurs in all four UK nations with Ofsted (the Office for Standards in Education, Children's Services and Skills) being the non-ministerial department responsible for school inspection (amid other responsibilities) in England. Ofsted was established in 1992, under a Conservative government, amidst a quite widespread presumption that school standards were not improving. Prior to this, HMI (His Majesty's Inspectorate) undertook a certain number of inspections of schools in England but these were not systematic and HMI, which was smaller than Ofsted, had a particular responsibility to informal government in relation to policy matters (Lee & Fitz, 1997).

In Ofsted's first Annual Report, Professor Sutherland, the first chief Inspector of Ofsted, wrote that the purpose of Ofsted, "is to make a contribution, through these inspections, to raising standards and improving the quality of educational experience and provision" (Ofsted, 1993) and this remains its main aim. However, since the introduction of the National Curriculum (in 1989) and Ofsted (in 1992), central government (of whatever political persuasion) has increasingly been accused of micromanaging the teaching and administration of schools, and in pillorying schools that do not conform. Ofsted has, in effect, become a government enforcement agency with less independence than its HMI predecessor.

Neoliberalism in UK school education

Jeffries, A. C., McCrory, A. & Reiss, M. J. (2024) The contribution of socioscientific issues to science education: A United Kingdom perspective. In: *A Moral Inquiry into Epistemic Insights in Science Education: Personal and Global Perspectives of Socioscientific Issues*, Zeidler, D. L. (Ed.), Springer, Cham, pp. 387-408. https://doi.org/10.1007/978-3-031-63382-9_20.

Since the 1980s, neoliberalism has increasingly been the dominant ideology shaping school education policy in the UK. It has been argued that the school education system should be managed according to the principles of a free market. Thus, neoliberals believe that education should be privatized both endogenously, promoting competition between schools to incentivize them to raise standards, and exogenously, enabling private companies to take over education services which had been previously managed by the public sector.

In 1988, the Education Reform Act, which heralded the introduction of the National Curriculum, was enacted by the Conservative government; it was strongly influenced by neoliberal ideals. With the introduction of a statutory, and some would assert restrictive, National Curriculum and the introduction of new, standardized assessment practices in schools, it was maintained by the government that both primary and secondary schools were given the tools needed to raise standards of achievement for the students they served (MacBeath & McGlynn, 2004). At the same time, school league tables were introduced, with the promise that this would empower parents to judge and compare schools in the best interest of their child's education.

In doing this, parental choice was highlighted as an important factor of an educational market, but the reality was that schools were forced to engage in hyper-competitive practices, such as single-mindedly focusing on getting the best possible grades to the detriment of a more holistic education (Ball, 2016). And so, from this emerged a pervasive culture of performativity in schools, producing a high stakes environment with the tendency for teachers to 'teach to the test' to ensure student grades and measures of school performance aligned with what was, and still is, seen as acceptable assessment benchmarks. Formula funding for schools was also introduced, meaning that schools then needed to compete to a greater extent for students. This policy, inevitably, led to polarization across schools with those deemed 'best' being oversubscribed and those deemed 'worst' being under-funded, leading to significant wealth inequalities whilst widening the education inequality gap (Gray et al., 2018).

Integral to a neoliberal approach to education is the argument that both parents and students are given more agency, choice and voice whilst standards in schools are monitored via a top-down approach of surveillance and performance management. This has been and continues to be achieved via a focus on teachers' performativity which can be defined as "a mode of regulation that employs judgements, comparisons and displays as a means of incentive, control, attrition and change: (Ball, 2003, 216). There can be a set of rigid conventions to which teachers feel they must adhere in order to be considered 'good' teachers. Neoliberalism argues that all learners will perform and succeed in standardized testing if taught as deemed appropriate, thus meaning that performance management provides a sure-fire way to raise educational standards.

Critics of neoliberalism have consistently pointed out that education is not an industry; rather, teachers are professionals and not technicians (Ball, 2003). Classrooms are environments of teaching and learning and not production lines. Schools are a microcosm of society, not factories. In schools, students and teachers (should) work and live together in a learning community, working collaboratively to nurture and promote students' interests and abilities by engaging in the scholarship of learning; but the neoliberal agenda prevails (Gray et al., 2018). This is despite the fact that neoliberalism tends to perpetuate, even accentuate, educational inequalities by prioritizing market-based solutions over and above the common

Jeffries, A. C., McCrory, A. & Reiss, M. J. (2024) The contribution of socioscientific issues to science education: A United Kingdom perspective. In: *A Moral Inquiry into Epistemic Insights in Science Education: Personal and Global Perspectives of Socioscientific Issues*, Zeidler, D. L. (Ed.), Springer, Cham, pp. 387-408. https://doi.org/10.1007/978-3-031-63382-9_20.

good. Free markets tend to advantage those with capital and resources. Exposing schools to market forces can therefore be detrimental to students who come from disadvantaged backgrounds (Ingleby, 2021) as they often lack sufficient resources or navigational capital (Yosso, 2005) to get into the best schools in the open educational market. If schools are to narrow the pervasive attainment gap for children from disadvantaged backgrounds, which evidence suggests is already present when children come to school, then teaching for engagement is key. This includes building on the ideas that students bring to lessons and helping children to build self-regulation for intrinsic motivation.

A different and more recent criticism of neoliberal approaches to education has come, particularly post-COVID, from an increasing acknowledgement that the present system of education in England is unhealthy for many students and teachers. It is generally accepted (Glazzard, 2018) that children's mental health has deteriorated in recent decades in the UK (Pitchforth et al., 2019) and that teachers have high levels of stress and low and deteriorating levels of mental health (Kidger et al., 2016). Much has been written in the popular press and professional literature about the impact of school inspections and other aspects of the neoliberal apparatus on the mental health and well-being of school staff, including those in leadership. The recent tragedy of primary school headteacher Ruth Perry, who took her own life in 2023 after an Ofsted inspection downgraded her school from the top grade ('outstanding') to be bottom one ('inadequate') is one such example which hit the headlines. An independent coroner's inspection concluded that Perry's cause of death was "Suicide, contributed to by an Ofsted inspection carried out in November 2022" (Connor, 2023).

There has understandably therefore been a backlash against the neoliberal culture in which schools currently operate. Critics of neoliberalism argue that a neoliberal focus on school education omits much of value that schools can and should do. Critics also maintain that to raise standards and ensure effective student progress, schools must become more autonomous and collegial entities, responsible for their own development and for the demographic they serve. In order to achieve this, instead of an excessive focus on external inspection, as though schools are only concerned with the cognitive output of students, as measured via an obsessive focus on examination outcomes, internal accountability and self-evaluation is needed via moderation in and across schools and governing bodies so that the school itself can answer the fundamental question: 'Are standards as good as they can be?' (Ball, 2016).

The contribution of SSI to school science education

The neoliberal approach to education fails to take into account the complexity of the learning needs present in any science classroom and the diverse demographic of students that science teachers serve. The irony here, which we are sure is not lost on the reader, is that this approach can prevent creative and innovative approaches to teaching, which are likely ultimately to help the UK's economy, given that the UK is increasingly a knowledge and service economy. A narrow neoliberal approach to education, including STEM (Science, Technology, Engineering and Mathematics) education, means that learners are more likely to be disengaged, with deeper, critical thinking skills not being sufficiently developed (cf. Bencze et al., 2018). Student engagement and interest are key to school students "learning a body of knowledge relating to the products and practices of science … and developing a sense of excitement and curiosity about natural phenomena" (Ofsted, 2021). One way in which this can be achieved is when science courses personalize and localize science learning by emphasizing the links between science and everyday life, as this has been shown to foster more positive attitudes to science and school science (Bennett et al., 2007).

A high stakes neoliberal environment, an overburdened science curriculum, and the constant pressure for students to perform at their very best in standardized tests is not a conducive environment for the teaching and learning of SSI. Engaging in interdisciplinary learning, inquiry-based learning, problem-based projects, real-life problem solving, critical thinking, discussion, and perspective taking does not translate well into a neoliberal perspective which is built on a narrow conceptualization of teaching and learning. This, we argue, goes a long way to accounting for why SSI approaches to science education are still underutilized in schools in the UK. Nonetheless, there has been a gradual turn to utilizing SSI in school science education, particularly at secondary level but also in primary schools where the existence of a culture of cross-curricular teaching and project-based learning provides fertile ground to employ SSI (McCrory & Reiss, 2023).

For science teachers, a neoliberal environment can also have a profound impact on their agency as well as on the development of their professional identity, pedagogy, and views regarding the teaching of science. This can cause conflict between personal and professional values in relation to the aims of science education. Am I teaching this because it is important, worthwhile and aligns with my own teaching ethos or simply because ultimately it will help my students and my school to perform better when their performance is assessed and compared with others? We are not, of course, against learners and schools doing well in assessment; rather, our point is two-fold: first, some of the best teaching can result in valuable learning that cannot be assessed in national tests and examinations; secondly, the present system of national tests and examinations in the UK, perhaps especially in England, is based on a much narrower conceptualization of learning than could (should) be the case. The reality of a neoliberal approach in the science classroom can mean that there is the potential not only to impact negatively on the educational achievement of some learners, but also on the development of their scientific literacy, epistemic insight and knowledge, as well as their aspirations to become scientists or work in scientific fields (McCrory & Reiss, 2023).

We live in a highly connected and globalized world, but one that remains in some ways fragmented. Science operates within a landscape of rapid technological change with uncertainty about the impact of this and what the future might look like, including concerns that humanity is facing threats to its continued existence (Reiss, 2023). If we take, for example, the current debate surrounding Artificial Intelligence, a clear example of technological advancement which is challenging to keep up with and is beginning to impact education and our daily lives in unprecedented ways, we can see the complexity of the issues and sympathize with the concerns voiced. This is an example of a socially relevant, multi-disciplinary issue, based in science, and which has the potential to have a significant impact on society – an SSI.

Science teachers in England are now expected to address matters which have previously been the province of teachers of history, PSHE (Personal, Social, Health and Economic) education, and even Religious Education. Ofsted inspection requirements stipulate that a school's intention to provide for the personal development of all students must be a whole school

Jeffries, A. C., McCrory, A. & Reiss, M. J. (2024) The contribution of socioscientific issues to science education: A United Kingdom perspective. In: *A Moral Inquiry into Epistemic Insights in Science Education: Personal and Global Perspectives of Socioscientific Issues*, Zeidler, D. L. (Ed.), Springer, Cham, pp. 387-408. https://doi.org/10.1007/978-3-031-63382-9_20.

issue. Schools are required to demonstrate how their programs of personal development aim to enable their students to develop into responsible, respectful, and active citizens who are able to play their part and become actively involved in public life as adults. This should be achieved by developing students' character, dispositions, and virtues that inform their motivation and guide their conduct so that they reflect wisely, learn eagerly, behave with integrity, and cooperate with others. In 2008, changes to the science National Curriculum (for 11–16-year-olds) for England and Wales encouraged the recognition of the role of controversy in science. Subsequent changes to the National Curriculum for science in 2015 require 14–16-year-old students to learn about practical and ethical considerations of modern biotechnology (DfE, 2015, 10). Aims across the whole of the 5-16 age range include ensuring that students are "equipped with the scientific knowledge required to understand the uses and implications of science, today and for the future" (DfE, 2015, 2).

Specific references to SSI and scientific debate are lacking from the current (DfE, 2015) primary science National Curriculum (for 5–11-year-olds), with guidance stating that the "social and economic implications of science are important but, generally, they are taught more appropriately within the wider school curriculum" (DfE, 2015, 2). However, topics within the primary science National Curriculum include adaptation, evolution, deforestation, diet, drugs, nutrition, materials, microorganisms, exploring human impact on ecology, and studying scientists and their work. Clearly there is room here for discussion and debate in the primary science classroom, and the primary science National Curriculum also states that teachers will, "wish to use different contexts to maximize their pupils' engagement with and motivation to study science" (DfE, 2015, 3). We take the view that this does in fact give schools the freedom and agency to teach in ways that they see best, so long as the statutory requirements are adhered to.

Teaching in primary schools in the UK is not normally compartmentalized by subject in the way that it typically is in secondary schools. By and large (there can be exceptions, such as music and Physical Education), in primary schools, the one teacher teaches all subjects to a class. Take, for example, the suggestion in the primary science programme of study (DfE, 2015) that when learning about materials, students might wish to learn about people who have developed useful materials, for example John Dunlop and the invention of pneumatic tyres. Using their scientific research skills, it should hopefully not take long for a student to raise the ethical issue of the impact of rubber plantations on endangered species and the broader ecology in Southern and Eastern Asia (Figure 1). In certain areas of the curriculum, e.g., PSHE education and citizenship, teachers are encouraged to undertake activities such as 'circle time' to discuss various issues such as bullying, and, with older students, drugs and relationships education. Citizenship, which advocates the teaching of controversial issues, can provide approaches and strategies for teachers when planning to teach SSI, since engaging in citizenship learning involves clarifying values, evaluating information and viewpoints, discussion, and decision making (Woolley, 2010). Fortunately, whole school approaches to cross-curricular teaching in primary schools enable students to make links between subjects and for teachers to deliver a curriculum that is enriched.

Jeffries, A. C., McCrory, A. & Reiss, M. J. (2024) The contribution of socioscientific issues to science education: A United Kingdom perspective. In: *A Moral Inquiry into Epistemic Insights in Science Education: Personal and Global Perspectives of Socioscientific Issues*, Zeidler, D. L. (Ed.), Springer, Cham, pp. 387-408. https://doi.org/10.1007/978-3-031-63382-9_20.

Figure 1. Rubber plantation in Kerala, India. Rubber plantations damage native forests and cause other ecological problems. On the other hand, they can support local economies. https://commons.wikimedia.org/wiki/File:Rubber_plantation,_Kerala_01.jpg

The contribution of SSI to Visions of science education

Roberts and Bybee (2014) who build on Roberts' (2007) give a helpful conceptualization of the two contrasting visions for science education – Vision I and Vision II:

> "Vision I looks inward at science, to build curriculum from its rich and well established array of techniques and methods, habits of mind, and well-tested explanations for the events and objects of the natural world. Literacy, in this view, is within science – general familiarity and fluency within the discipline, based on mastering a sampling of the language, products, processes, and traditions of science itself.
>
> Vision II, developed later in the history of school science, begins by looking outside science to build curriculum that illuminates how science permeates and interacts with many areas of human endeavor and life situations. These societal issues and individual life situations usually include political, economic, and ethical considerations. This view is sometimes called science for citizenship, concentrating on matters of more obvious personal and social relevance to students than preparing to grasp more demanding science they might or might not study. The slogan "science for all" represents a viewpoint that all students need some introduction to citizen

Jeffries, A. C., McCrory, A. & Reiss, M. J. (2024) The contribution of socioscientific issues to science education: A United Kingdom perspective. In: *A Moral Inquiry into Epistemic Insights in Science Education: Personal and Global Perspectives of Socioscientific Issues*, Zeidler, D. L. (Ed.), Springer, Cham, pp. 387-408. https://doi.org/10.1007/978-3-031-63382-9_20.

science, including such matters as environmental quality, resource use, personal health, and decision making about complex socioscientific issues." (Roberts & Bybee, 2014, 546)

More recently, Sjöström and Eilks (2018) have conceptualized what they term 'Vision III' to include 'critical scientific literacy' and 'socio-political action'. This builds on earlier ideas of such authors as Hodson (1994), Roth and Barton (2004) and Aikenhead (2007). Vision III therefore has various elements to it. It builds on Visions I and II in that it requires a good understanding of science (Vision I) and is a science education for all (Vision II) but it extends these to integrate both cognitive and affective domains including politicization to address complex SSI.

Increasingly, school science courses attempt to combine Visions I and II in order to serve the majority of students and the minority who will go on to be scientists, or at least use science to a certain extent in their paid employment. However, utilizing SSI in school science courses actually has the potential to address all three Visions in a meaningful way.

How can SSI be utilized to promote scientific literacy, epistemic insight and human flourishing in science education?

Fostering students' appreciation of the epistemology of science is an important goal of science education, one that has only grown in importance in recent years as misinformation in science has increased and trust in science has decreased (Reiss, 2022; Osborne & Pimentel, 2023). Understanding the nature of science and developing scientific literacy so that students can not only apply epistemological knowledge to school science, but also participate effectively in civic and cultural affairs is important. At a personal level, it is desirable for students to be able to make informed decisions and judgements regarding what matters to them using their understanding of scientific concepts and processes (Archer et al., 2013).

Indeed, it has been argued that science education can contribute to human flourishing (Reiss & White, 2014). In writing about this, Reiss and White (2014, 83) note, "how difficult it is to pigeon-hole knowledge into discrete school subjects", indicating that an approach to school science education that makes good use of SSI is more likely to contribute to human flourishing. One way therefore for educators to promote scientific literacy, epistemic insight and human flourishing is to empower students through the study of SSI that connect with their interests, values and experiences so that they can become reflective citizens who engage in, and are a part of, a society that neither disparages nor worships science.

Perhaps one of the most important aspects of teaching is student motivation (Silva, 2006); for many students learning science, whether at primary, secondary or tertiary levels, engagement in contemporary issues can help stimulate interest. As Reiss (2009) notes, consideration of ethical issues in school science can enhance student motivation; however, as he points out, "it is perhaps unsurprising that for many young people it is the ethical issues raised by science that too often seem to be lacking from their science lessons" (p.137). If the social, cultural and ethical aspects of science were included more fully in school science, many students might be encouraged to study science longer, as the humanistic side of science appeals to many learners, particularly girls and young women (Davila Dos Santos et al., 2022). It is

Jeffries, A. C., McCrory, A. & Reiss, M. J. (2024) The contribution of socioscientific issues to science education: A United Kingdom perspective. In: *A Moral Inquiry into Epistemic Insights in Science Education: Personal and Global Perspectives of Socioscientific Issues*, Zeidler, D. L. (Ed.), Springer, Cham, pp. 387-408. https://doi.org/10.1007/978-3-031-63382-9_20.

therefore encouraging that in a bid to enable more students to enjoy studying science as well as to help them to become more ethically sensitive, some schools have been including more SSI within their science curricula (Hancock et al., 2019).

Science teaching is complex, and the measure of success is not simply about ensuring good summative results in standardized tests such as those at the end of secondary schooling, although, given the structure of the education system in the UK, this is an important step to continuing to study science once it is no longer compulsory. There is now a considerable body of evidence that effective teaching in science must start from the beginning of a learner's time in school by ensuring their engagement and developing their commitment to learn (Bennett et al., 2023). We are sure that science teachers across all age ranges can identify with the moments when curiosity and interest in science have been sparked, and the sense of satisfaction this brings to both student and teacher alike (e.g., Pugh et al., 2010). The quality of science teaching is therefore a major determinant of student engagement and attainment, whilst high quality teaching can support and develop positive attitudes to science. Zeidler et al. (2011) have shown that an SSI approach to science education, when fully enacted, can become a transformative process for participating students and their teachers. In addition to the reasons that we have already considered, this is in part because SSI teaching entails a shift to a more student-focused pedagogy, which itself tends to engage learners.

In the UK, there is an engagement problem in school science with declining attitudes beginning to emerge by the end of primary school (9–11-year-olds). Many students by the age of 14 feel that science is 'important, but not for me' and this is worrying, given that pursuing further study in science is largely determined by this age (Sheldrake et al., 2019). Why is this when students do in fact recognize the value of science? Furthermore, we are living at a time when significant numbers of young people are realizing the power they have to effect social change, using social media to demonstrate their agency and voice so as to have an impact (Fullam, 2017). In 2019, a series of school strikes organized by young people, inspired by a then 16-year-old Greta Thunberg's protests regarding inaction on climate change, saw more than a million young people take part in demonstrations across the world. It is therefore evident that students understand that science is powerful but there is too often a disconnect between school science and the real world. For many students, science is not relevant to their daily lives and school science does not focus on the issues for which they are impassioned and matter to them. This is one of the principal reasons why SSI have a central place in school science.

Learning progressions in SSI

Finally, if SSI are to play a more prominent role in science, whether at primary, secondary or tertiary level, it is important that students are enabled to progress in their learning. If one thinks of a topic like the theory of evolution, there is a degree of consensus about what one might expect learners at different stages of their education to be studying (Wyner & Doherty, 2017; Moore & Graham, 2021). However, consensus about progression in SSI – what we would expect learners to know at roughly what age, and in what order, and how this might be assessed – are less advanced. We report now how one in-depth study looked at the understandings of SSI among primary children in England and at what was found about their learning progressions.

Jeffries, A. C., McCrory, A. & Reiss, M. J. (2024) The contribution of socioscientific issues to science education: A United Kingdom perspective. In: *A Moral Inquiry into Epistemic Insights in Science Education: Personal and Global Perspectives of Socioscientific Issues*, Zeidler, D. L. (Ed.), Springer, Cham, pp. 387-408. https://doi.org/10.1007/978-3-031-63382-9_20.

McCrory (2014) explored the capabilities of 7–8-year-olds, in relation to their perceptions, knowledge and understanding of SSI in tandem with their ability to think morally and scientifically. Three schemes of work – 'Morals', 'Energy' and 'Genetics' – were taught to 21 Year 3 students, one topic per term, across one academic year. Lessons were carefully planned to take into account the students' cognitive capabilities, especially important when considering topics such as genetics. SSI were used that were raised by the children themselves which either affected them or their families or arose from their engagement with film and media. For example, topics such as cloning and genetic inheritance arose due to watching *Star Wars* films, reading newspaper reports about Dolly the Sheep, and talking about inherited genetic diseases, e.g., sickle-cell anemia which one of the children in the class had and openly shared. A discussion of the merits of luminous zebra fish which glow green when put in polluted water was a focus after being reported via Children's BBC Newsround television program. The effects of climate change (for example, flooding) on countries such as Bangladesh (a country where many children in the class had relatives) were also a focus.

In line with thinking about pedagogical content knowledge (Pollard et al., 2023) and relevant research on teaching SSI at primary level, lessons incorporated a variety of pedagogies, including argumentation, role-play, pictorial representations, mind-maps, concept cartoons, dialogic talk, and reporting. Outcomes indicated that students' moral thinking when considering SSI was underpinned by their belief in the following values:

- *Being fair*. For example, when discussing renewable energy, one student commented:

  > It's very unfair when we [humans] pollute habitats, like when there was that ship that spilt loads of oil into the sea. The birds were covered in oil and they couldn't fly and the fish died, lots were washed up on the beach. It made me feel really angry and upset, the poor birds and fish were suffering. If we used more renewable energy, like wind turbines, then that probably wouldn't happen as much because we would be using less oil.

  When considering the possibility of human cloning, one student stated: "Only the rich will be able to afford a clone and that's not fair to the poor."

- *Honesty and truthfulness*. For instance, when considering recycling, one student said:

  > Sometimes people don't recycle because they can't be bothered even though they know that they should … and then some people say that they recycle even when they don't, so they lie which is silly. Maybe it's because they are embarrassed?

  In another example, when thinking about a dilemma based on inherited diseases, one student said of one of the protagonists: "She has to tell her partner [about having the faulty gene] … the partner will not get angry with her because she has told the truth".

- *Respect*. For example, when thinking about their local environment, one student said:

  > When we throw rubbish on the ground and litter in the parks we are disrespecting it [the environment] and that's wrong. It looks disgusting, birds

can choke on food wrappings, it makes the water dirty … Once, I saw a bike in a pond!

When considering whether or not to use a human clone for their own future benefit, one student said: “We are not respecting the clone … We’d be saying that we’re better than the clone and that it is not worth anything which is really terrible, because it would be a person just like me”.

- *Being responsible and considering the welfare of others*. For instance, when thinking about the behavior of some of the engineers at the Chernobyl plant, one student argued: “They didn’t think about anyone but themselves. They didn’t care that other people might get hurt or die”.

In terms of learning progression, the aim of the assessment frameworks in Table 1 and Table 2 (McCrory, 2014), is to promote the knowledge, understanding, and skills needed when teaching scientific and moral decision making to children of primary age. The work that led to these two tables entailed initially presenting the students with moral dilemmas, followed by presenting them with SSI which demanded both moral and scientific decision-making skills. The children were given repeated opportunities to become aware of and identify with their own moral values, to promote moral awareness and development, since clarification of values is integral to moral education. The lessons aimed to help the children to develop a critical appreciation of issues of right and wrong, fairness, rights and obligations in society, and to promote social awareness and development through helping them to begin to acquire relevant knowledge, understanding and skills.

Studies suggest that children apply multiple forms of reasoning, namely moral (fairness, justice, rights), conventional (customs, etiquette) and psychological (autonomy, identity), simultaneously when evaluating transgressions or social dilemmas. The frameworks in Table 1 and Table 2 were constructed to help analyze the children’s statements, not to neatly categorize the children’s responses into separate sub-levels as can be the norm in primary school assessment in the UK.

Table 1. Framework for the determination of moral thinking and perspective taking when reasoning about SSI in the primary school.

Level	Criterion	Example(s)
MTPT0	No use of moral thinking or perspective taking.	When asked to consider whether anything might be wrong about choosing the hair color or sex of a child when designing babies Sh replied, “If you choose too many boys, then we won’t be able to make as many babies [in the future] because you need a boy and a girl to make a baby”.
MTPT1	Some use of moral thinking or perspective taking but manifests moral misconception(s).	When asked “Should we clone humans?”, V replied, “There will be a population increase which means that there will not be enough homes. So, poverty will rise and

		only people who are rich will be able to pay which is unfair to the poor. Also, more food will be needed so species of animals may die out".
MTPT2	Student identifies a moral concern/dimension in a SSI but is unable to reason further (for example, to explore intentions and consequences or take more than one perspective).	When thinking about why the two engineers responsible for the Chernobyl disaster carried on with their experiment, R wrote, "They were selfish, they didn't care". R was unable to explain this any further.
MTPT3	Student analyses the morality of a specific SSI using intentions and consequences and/or demonstrating perspective taking.	When deciding whether or not Jane [a character who has inherited Huntington's disease] should tell her partner, M wrote, "She has to tell her partner [about having the faulty gene] because then her partner will know. And when she says, 'I might die', the partner will not get angry because she told the truth".
MTPT4	Student analyses the morality of a specific SSI using intentions and consequences and/or demonstrating perspective taking and makes a decision about what to do using moral language and thinking.	When asked to consider "What if, in the future, we could make a clone of ourselves and keep him/her to use in case we became ill?", V noted, "We are not respecting the clone", followed by Sh adding "We'd be saying that we're better than the clone, that it's worthless and that it doesn't have any human rights".
MTPT5	Student uses moral language and understanding to ask abstract questions to further his/her knowledge and understanding of SSI.	When asked "What if, in the future, we could make a clone of ourselves and keep him/her to use in case we became ill?", S questioned, "But what if the clone refuses to give away their heart [if needed] because they know that they won't live? Then, that's not right and I'd feel guilty".

Table 7.2. Framework for the determination of scientific knowledge and understanding when reasoning about SSI.

Level	**Criterion**	**Example(s)**
SKU0	No use of scientific knowledge or understanding	When asked, "Do you know what climate change is?", J responded "No".
SKU1	Some use of scientific knowledge or understanding but there is evidence of scientific misconception(s) or a lack of scientific knowledge.	V asked, "If you are not married and have a baby on your own, does it mean that it will only have 23 chromosomes?".

SKU2	Student identifies a cause or an effect of a problem using scientific knowledge, or understanding, but is unable to reason further (for example, to link causes and effects).	K stated, "A genetic disease is a disease which is passed on to you by your mother and father, in your genes" but was unable to elaborate further about this.
SKU3	Student gives an advantage or disadvantage of a specific SSI or identifies its risk(s) and makes a decision about what to do using scientific reasoning.	When deciding whether or not Jane [a character who has inherited Huntington's disease] should have children of her own, E includes risk analysis in her explanation: "No, she should not have children because if she has children then they might inherit Huntington's disease [so] she is taking a risk.'
SKU4	Student identifies and links causes and effects of a SSI using the correct scientific knowledge and understanding.	When considering the impact of the Chernobyl disaster, S identifies the cause of the explosion as well as multiple consequences: "Caused by engineers playing with the safety valves. Impacts: radioactive clouds, massive fire for ten days, people lost their lives, people got cancer, livestock died, farmers lost their money, bad relations between countries, people were unhappy".
SKU5	Student proposes possible solutions and gives reasons for these.	When asked "What can we do to combat climate change?", M replied, "Fuel-efficient transport means using less fuel and producing less carbon dioxide. Using transports like moped, bicycle, train, and bus uses less energy. If you use a bicycle it uses far less energy than a car".
SKU6	Student uses scientific knowledge and understanding to ask abstract questions to further his/her knowledge and understanding of science without prompting or cues from the teacher.	When discussing renewable energy, S asked, "Do people use man-made chlorophyll to work solar panels?".

It is important to distinguish between what is desirable and what is possible when evaluating learning of SSI. Authentic evaluation is difficult to achieve due to the relationship between "education and behavioural outcomes … and the practicality of authentic assessment" in the classroom (Ratcliffe & Grace, 2003, 41). In addition, in a neoliberal environment where accountability of students' attainment and progress is high on the agenda, it is important to present science teachers with assessment frameworks which 'work'. In the case of the frameworks and approach devised by McCrory (2014), primary classroom science teachers

Jeffries, A. C., McCrory, A. & Reiss, M. J. (2024) The contribution of socioscientific issues to science education: A United Kingdom perspective. In: *A Moral Inquiry into Epistemic Insights in Science Education: Personal and Global Perspectives of Socioscientific Issues*, Zeidler, D. L. (Ed.), Springer, Cham, pp. 387-408. https://doi.org/10.1007/978-3-031-63382-9_20.

would be able to apply the frameworks not only for summative assessment that links to the National Curriculum but also, and which is perhaps more pertinent in relation to primary teaching pedagogy of science, for in-the-moment formative assessment.

References

Aikenhead, G. S. (2007). Expanding the research agenda for scientific literacy. In: Linder, C., Östman, L. & Wickman, P.-O. (Eds.), *Promoting Scientific Literacy: Science Education Research in Transaction,* Geotryckeriet, pp. 64–71.

Archer, L., Osborne, J., DeWitt, J., Dillon, J., Wong, B., & Willis, B., (2013). *ASPIRES: Young people's science and career aspirations, age 10–14*. King's College London.

Ball, S. J. (2003). The teacher's soul and the terrors of performativity. *Journal of Education Policy*, 18(2), 215–228.

Ball, S. J. (2016). Neoliberal education? Confronting the slouching beast. *Policy Futures in Education*, 14(8), 1046–1059.

Bencze, L., Reiss, M. J., Sharma, A., & Weinstein, M. (2018). STEM Education as "Trojan Horse": deconstructed and reinvented for all. In: *13 Questions: Reframing Education's Conversation – Science*, Bryan, L. A. & Tobin, K. (Eds), Peter Lang, pp. 69–87.

Bennett, J., Lubben, F., & Hogarth, S. (2007). Bringing science to life: a synthesis of the research evidence on the effects of context-based and STS approaches to science teaching. *Science Education*, 91(3), 347–370.

Bennett, J. M., Dunlop, L., Atkinson, L., Compton, S., Glasspoole-Bird, H., Lubben, F., Reiss, M. J., & Turkenburg-van Diepen, M. (2023). *A Systematic Review of Approaches to Primary Science Teaching*, Endowment Education Foundation. Available at https://d2tic4wvo1iusb.cloudfront.net/production/documents/guidance/systematic-review-of-approaches-to-primary-science-teaching.pdf?v=1701173359.

Bryant, J. A., & la Velle, L. B. (2018). *Introduction to Bioethics, 2nd edn*. John Wiley & Sons.

Connor, H. (2023). *Regulation 28: Report to Prevent Future Deaths.* https://www.judiciary.uk/wp-content/uploads/2023/12/Ruth-Perry-Prevention-of-future-deaths-report-2023-0524_Published-1.pdf.

Davila Dos Santos, E., Albahari, A., Díaz, S., & De Freitas, E. C. (2022). 'Science and Technology as Feminine': raising awareness about and reducing the gender gap in STEM careers. *Journal of Gender Studies, 31(4), 505–518.*

DfE (Department for Education) (2015). *National Curriculum in England: Science Programmes of Study*. Department for Education. https://www.gov.uk/government/publications/national-curriculum-in-england-science-programmes-of-study

Jeffries, A. C., McCrory, A. & Reiss, M. J. (2024) The contribution of socioscientific issues to science education: A United Kingdom perspective. In: *A Moral Inquiry into Epistemic Insights in Science Education: Personal and Global Perspectives of Socioscientific Issues*, Zeidler, D. L. (Ed.), Springer, Cham, pp. 387-408. https://doi.org/10.1007/978-3-031-63382-9_20.

Department for Science, Innovation & Technology and Prime Minister's Office (2024). *Policy Paper: The UK Science and technology Framework*. https://www.gov.uk/government/publications/uk-science-and-technology-framework/the-uk-science-and-technology-framework.

Duncombe, M. (2023). Stoicism on Tiktok promises happiness – but the ancient philosophers who came up with it had something very different in mind. *The Conversation*, 16 November. https://theconversation.com/stoicism-on-tiktok-promises-happiness-but-the-ancient-philosophers-who-came-up-with-it-had-something-very-different-in-mind-216693.

Fullam, J. (2017). Becoming a youth activist in the internet age: a case study on social media activism and identity development. *International Journal of Qualitative Studies in Education*, 30(4), 406–422.

Glazzard, J. (2018). The role of schools in supporting children and young people's mental health. *Education and Health*, 36(3), 83–88.

Grant, C. (2017). *The Contribution of Education to Economic Growth*. K4D Helpdesk Service. https://assets.publishing.service.gov.uk/media/5b9b87f340f0b67896977bae/K4D_HDR_The_Contribution_of_Education_to_Economic_Growth_Final.pdf.

Gray, J., O'Regan, J. P., & Wallace, C. (2018). Education and the discourse of global neoliberalism. *Language and Intercultural Communication*, 18(5), 471–477.

Hancock, T. S., Friedrichsen, P. J., Kinslow, A. T., & Sadler, T. D. (2019). Selecting socio-scientific issues for teaching: a grounded theory study of how science teachers collaboratively design SSI-based curricula. *Science & Education*, 28, 639–667.

Hodson, D. (1994). Seeking directions for change: the personalisation and politicisation of science education. *Curriculum Studies*, 2(1), 71–98.

Ingleby, E. (2021). *Neoliberalism across Education*. Springer International.

Kidger, J., Brockman, R., Tilling, K., Campbell, R., Ford, T., Araya, R., ... & Gunnell, D. (2016). Teachers' wellbeing and depressive symptoms, and associated risk factors: a large cross sectional study in English secondary schools. *Journal of Affective Disorders*, 192, 76–82.

Lee, J., & Fitz, J. (1997). HMI and OFSTED: evolution or revolution in school inspection. *British Journal of Educational Studies*, 45(1), 39–52.

MacBeath, J., & McGlynn, A. (2004). *Self-evaluation: What's in it for Schools?* Routledge.

McCrory, A. (2014). *Investigating the Moral and Scientific Thinking of 7-8 year olds when taught Socioscientific Issues related to Energy and Genetics*. Unpublished PhD thesis. University of London, Institute of Education.

McCrory, A., & Reiss, M. J. (2023). *The Place of Ethics in Science Education: Implications for Practice*. Bloomsbury.

Menn, S. (1997). Physics as a Virtue. In: *Proceedings of the Boston Area Colloquium in Ancient Philosophy*, vol. XI, Cleary, J. J. and Wians, W. C. (eds), Lanham, pp. 1–34.

Miller, S., & Selgelid, M. J. (2007). Ethical and philosophical consideration of the dual-use dilemma in the biological sciences. *Science and Engineering Ethics*, 13(4), 523–580.

Moore, A. & Graham, C. (2021). Evolution. In: *Teaching Secondary Biology, 3rd edn*, Reiss, M. J., & Winterbottom, M. (Ed.s), Hodder Education, pp. 207–227.

Ofsted (1993). *Standards and Quality in Education 1992-93*. HMSO.

Ofsted (2021). *Research Review Series: Science.* https://www.gov.uk/government/publications/research-review-series-science

Osborne, J., & Pimentel, D. (2023). Science education in an age of misinformation. *Science Education*, 107(3), 553–571.

Pitchforth, J., Fahy, K., Ford, T., Wolpert, M., Viner, R. M., & Hargreaves, D. S. (2019). Mental health and well-being trends among children and young people in the UK, 1995–2014: analysis of repeated cross-sectional national health surveys. *Psychological Medicine*, 49(8), 1275–1285.

Pollard, A., Wyse, D., Craig, A., Daly, C., Seleznyov, S., Harley, S., Hayward, L., Higgins, S., & McCrory, A. (2023). *Reflective Teaching in Primary Schools, 6th edn*. Bloomsbury.

Power, L., Millington, K. A., & Bengtsson, S. (2015). *Building Capacity in Higher Education Topic Guide*. The Health & Education Advice & Resource Team (HEART). https://assets.publishing.service.gov.uk/media/57a08984e5274a27b2000109/Capacity-Building-in-Higher-Education-Topic-Guide.pdf.

Pugh, K. J., Linnenbrink-Garciam L, Koskey, K. L. K., Stewart, V. C. & Manzey, C. (2010). Motivation, learning, and transformative experience: A study of deep engagement in science. *Science Education, 94, 1-28*

QAA (2019). *Subject Benchmark Statement: Physics, Astronomy and Astrophysics*. https://www.qaa.ac.uk/docs/qaa/subject-benchmark-statements/subject-benchmark-statement-physics-astronomy-and-astrophysics.pdf?sfvrsn=eff3c881_4.

QAA (2023). *Subject Benchmark Statement: Biosciences*. https://www.qaa.ac.uk/docs/qaa/sbs/sbs-biosciences-23.pdf?sfvrsn=b570a881_6.

QAA (2024). *Subject Benchmark Statements.* https://www.qaa.ac.uk/the-quality-code/subject-benchmark-statements.

Ratcliffe, M., & Grace, M. (2003). *Science Education for Citizenship: Teaching SocioScientific Issues*. McGraw-Hill Education.

Jeffries, A. C., McCrory, A. & Reiss, M. J. (2024) The contribution of socioscientific issues to science education: A United Kingdom perspective. In: *A Moral Inquiry into Epistemic Insights in Science Education: Personal and Global Perspectives of Socioscientific Issues*, Zeidler, D. L. (Ed.), Springer, Cham, pp. 387-408. https://doi.org/10.1007/978-3-031-63382-9_20.

Reiss, M. J. (2009). Ethical reasoning and action in STSE education. In: *International Handbook on Research and Development in Technology Education*, Jones, A., & de Vries, M. (Eds,), Sense, pp. 307–318.

Reiss, M. J. (2022). Trust, science education and vaccines. *Science & Education*, 31(5), 1263–1280.

Reiss, M. J. (2023). Science education at a time of existential risk. *School Science Review in Depth*, 105(389), 5–10.

Reiss, M. J., & White, J. (2014). An aims-based curriculum illustrated by the teaching of science in schools. *The Curriculum Journal*, 25(1), 76–89.

Roberts, D. A. (2007). Scientific literacy/science literacy. In: Abell, S. K., & Lederman, N. G. (Eds.), *Handbook of Research on Science Education*, Lawrence Erlbaum, pp. 729–780.

Roberts, D. A., & Bybee, R. W. (2014). Scientific literacy, science literacy, and science education. In: Lederman, N. G., & Abell, S. K. (Eds.), *Handbook of Research on Science Education, Volume II*, Routledge, pp. 559–572.

Roth, W. M., & Barton, A. C. (2004). *Rethinking Scientific Literacy*. RoutledgeFalmer.

RSB (2023). *The Accreditation Handbook*. RSB. https://www.rsb.org.uk/images/accreditation_home/RSB_Accreditation_Handbook_2024.pdf.

Sellars, J. (2006). *Stoicism*. Routledge.

Sheldrake, R., Mujtaba, T., & Reiss, M. J. (2019). Students' changing attitudes and aspirations towards physics during secondary school. *Research in Science Education*, 49, 1809–1834.

Silvia, P. J. (2006). Exploring the psychology of interest. Oxford University Press.Sjöström, J., & Eilks, I. (2018). Reconsidering different visions of scientific literacy and science education based on the concept of Bildung. In: Dori, Y. J., Mevarech, Z. R., & Baker, D. R. (Eds.), *Cognition, Metacognition, and Culture in STEM Education*, Springer, pp. 65–88.

The National Archives (2024). *Further and Higher Education Act 1992*. https://www.legislation.gov.uk/ukpga/1992/13/contents.

Woolley, R. (2010). *Tackling Controversial Issues in the Primary School: Facing Life's Challenges with your Learners.* Routledge.

Wyner, Y., & Doherty, J. H. (2017). Developing a learning progression for three-dimensional learning of the patterns of evolution. *Science Education*, 101(5), 787–817.

Yosso, T. J. (2005). Whose culture has capital? A critical race theory discussion of community cultural wealth. *Race, Ethnicity and Education*, 8(1), 69–91.

Zeidler, D. L., Applebaum, S. M., & Sadler, T. D. (2011). Enacting a socioscientific issues classroom: Transformative transformations. In T. D. Sadler (Ed.), *Socio-scientific Issues in the Classroom: Teaching, Learning and Research*, Springer, pp. 277–305).

Jeffries, A. C., McCrory, A. & Reiss, M. J. (2024) The contribution of socioscientific issues to science education: A United Kingdom perspective. In: *A Moral Inquiry into Epistemic Insights in Science Education: Personal and Global Perspectives of Socioscientific Issues*, Zeidler, D. L. (Ed.), Springer, Cham, pp. 387-408. https://doi.org/10.1007/978-3-031-63382-9_20.