# Foreword

**Clare Matterson**

It is almost 50 years since CP Snow commented upon what he saw as the divide between two cultures: artistic and scientific. This book offers an opportunity to consider that divide afresh and it would be intriguing to know what Snow would make of the situation today.

The editors of this book offer an optimistic perspective on the interplay between different disciplines and the benefits that can accrue from successful creative encounters – many funded through the Pulse and other strands of the Wellcome Trust's Engaging Science grants programme. In doing so they identify several cultures and demonstrate that, while the degree of disciplinary fragmentation may be much greater than in 1959, the extent of overlap between them is notable. In some ways this is recognition of the increasing complexity of the scientific world and the difficulty of establishing a single view of scientific endeavour. Equally, it raises the status of dialogue and activity between scientists and non-scientists from the status of 'nice to have' to 'essential'.

This is not to say that you will find within this book any universal truths about the ways in which formal and less formal approaches to science education and improving scientific literacy can be generated: indeed the authors are refreshingly candid about the challenges inherent in such collaborations. Nevertheless – this book is positive about the interplay between disciplines and is supportive of creating and finding teaching and learning opportunities in a variety of settings within and outwith classrooms.

Snow might well be dismayed to find that there are more and more scientific and artistic disciplines. However, it does not follow that this increasing variety leads to fewer opportunities to find 'creative' approaches to scientific understanding and 'scientific' approaches to creativity. This book does much to exemplify these opportunities and to showcase the best endeavours of professionals seeking to enhance the engagement between science and society.

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# Creative encounters: an introduction

In his study of the science of acting, Joseph Roach observes that 17th-century actors believed that an actor's passions were contagious: they could literally transform the audience's beliefs and moral values. In 21st-century London, the theatre director Katie Mitchell continues to investigate scientific understanding of the emotions in the immediacy of the rehearsal room. Drawn to the idea that emotions incite physical changes in the body, she has applied the work of the neuroscientist Antonio Damasio to the rehearsal process, thereby redefining the practices of acting through the study of science. Instances of scientific research influencing the arts are evident throughout history, just as scientists have drawn on metaphors and symbolism from the arts to describe their practices and processes. Science and the arts have informed each other by unfixing certainties, and by disturbing and challenging established modes of thought. Scientific and artistic experiments share a lack of linearity and certainty, although this way of thinking has not always been recognised in forms of education that have favoured rather more measurable and predictable outcomes.

This book is motivated by an ambition to reflect on the ways in which young people might explore the creative opportunities presented by collaborations between scientists and artists. Through a series of well-defined funding schemes that aimed to forge links between the arts, biomedical science and its ethical implications, the Wellcome Trust has had the opportunity to support young people's creative and critical engagement with socio-scientific subject matter. Detailed evaluations of these projects have raised broader issues about the ways in which science is perceived and understood by young people, the role of creativity in education and the power of collaboration to generate an enthusiasm for learning. The authors gathered together in this book have been invited to reflect on pedagogic questions raised by interdisciplinary educational practices, and to raise questions about the ways in which creative educational practices contribute to encouraging

young people to become informed citizens. This introductory chapter explicitly addresses the place of creativity in education, the ways in which dominant narratives of science have become embedded in educational discourse and the popular imagination, and the concept and practice of citizenship.

It is impossible to fully document the rich dialogues between artists, educationalists and scientists that occur in genuinely creative collaborations. Embracing the complexities that lie at the heart of these experiences invites us to struggle with inherited beliefs and prejudices about the social roles of the arts and sciences in education, and to be open to new conceptualisations of the relationship between forms of knowing that have sometimes been caricatured as distanced, categorised as different and characterised as inherently distinctive. In an attempt to make a provisional map of this rocky territory, we have chosen to group the essays in this volume around three conceptual themes: Wonder, Space and Narrative. Each of these themes illuminates educational questions about the dynamic relationship between science, citizenship and creativity. Each recognises that learning takes place when young people are invited to make connections between the social and personal, when they become both emotionally involved with their work and make informed judgements about the ethics and practices of science.

The first section explores the idea of wonder, in which authors have focused on the importance of beauty and the aesthetic to the processes of learning, how the possibilities of biotechnology have been explored by artists to release the moral imagination, how play and illusion help develop new relationships that enhance interpretations of our experience. Relationships and interconnections are treated in the theme of space in the second section. Throughout the world, physical spaces in schools are being transformed, maximising collegiality and promoting new metaphors and discourses of learning. Intermingling of

professional spaces between scientists and artists presents new opportunities for understanding illness, and performance in a hospital rather than the dedicated dramatic space of a theatre creates new forms of social participation. In the third section, on narrative and storytelling, we see how marginalised people have disrupted conventional science and educational discourses and have been able to tell their own authentic accounts of science. But we are also reminded that stories can be told through a variety of art forms, including dance, and that the process of creating and linking narratives in different forms is complex but rewarding.

Taken as a whole, this is a book that is intended to stimulate discussion and debate, to celebrate the creativity of those working in education and to raise provocative questions about how creative encounters between the arts and sciences might challenge young people's perceptions and ideas.

### Encountering citizenship and science

The types of collaboration and partnership discussed above might seem distant to science teachers dealing with the content necessary for students to pass examinations. Science at school is often perceived as based on laws and theories that appear to yield solid facts and, if there are stories to tell, these are often about the heroic individuals who revealed the laws. The laws of thermodynamics, the gas laws, Newton's laws of motion and natural selection stand as true, impressive bulwarks of the authority of scientific knowledge. From a student's – and indeed teacher's – point of view it can seem that these simply have to be learned, and that they are very distant from the humanistic concerns that are the very stuff of the arts. But developments in medicine and the biosciences, together with unprecedented access to information through the world wide web, have created new possibilities of partnership, participation and dialogue such that the paternalistic model of deference to scientific expertise is no longer tenable (Layton *et al.*, 1993; Nowotony *et al.*, 2005). For example, identification of genetic conditions at pre-

conception, pre-natal and post-natal stages have given urgency to ideas of rights, autonomy, personal risk and decision-making. The rights and identities of disabled people, the concept of disability, are particularly bound up with these developments. Citizens are no longer set apart from the science but those who seek to ensure such changes can be put to the advantage of the public have become scientific citizens (Michael and Brown, 2005).

In the practices discussed in this book there is a constant and dynamic entwining of an idea of science with an idea of citizenship. The counterpart to the scientific citizen mentioned above is the scientist as citizen. In his 1995 Nobel Prize acceptance speech, the eminent physicist and citizen-scientist Professor Joseph Rotblat told a story:

> Two wise men were arguing about the ancient civilization in their respective countries. One said: "my country has a long history of technological development: we have carried out deep excavations and found a wire, which shows that already in the old days we had the telegraph." The other man retorted: "we too made excavations; we dug much deeper than you and found…nothing, which proves that already in those days we had wireless communication!" (Rotblat, 1995)

Rotblat's story is illuminating in a number of ways. Although he was using the tale to refute the idea that the existence of nuclear weapons has prevented a world war since 1945, it also invites examination of the link between the history of civilisation and the history of technological development. It raises questions about the nature and genesis of ideas and evidence. It also encourages us to think about the connections between national narratives and the narrative of scientific progress.

Joseph Rotblat's personal narrative is equally enlightening. He left Poland shortly before Hitler's invasion and subsequently worked on the Manhattan Project developing the A-bomb. He later became a highly respected researcher of the applications of nuclear physics to medicine. However, his Nobel Prize was for peace not for science. From when he left the Manhattan Project at the end of the War, he devoted himself to activism, leading campaigns against nuclear arms proliferation until his death in 2005 at the age of 96. He was a passionate believer in the potential of science to create new knowledge and benefit humanity. However, he also asserted the responsibilities of scientists to think about how their work would impact on society, reminding them that "the ivory tower was finally demolished by the Hiroshima bomb" (Rotblat, 1995). He felt that developments in science and technology had the potential to bring people together but also brought new risks, which, in turn, required new loyalties that crossed national boundaries and gave new responsibilities to scientists and citizens. He could not separate his personal narrative from his professional life, nor could he separate his ideas about science from his ideas about citizenship. He promoted an idea of global citizenship as an explicit and necessary response to his understanding of scientific progress.

The exact nature of public fears in the nuclear age may seem a bit outdated now. However the challenges faced by the next generation of citizen-scientists and scientific citizens will be arguably even greater. In 2007 the Nobel Peace Prize was won by the Intergovernmental Panel on Climate Change (IPCC) jointly with Al Gore. The IPCC has been the focus for collaboration among thousands of scientists from all over the world. It has been driven by a recognition that to understand the phenomenon of climate change, imagine its implications and find ways to address these, it will require an unprecedented level of cooperation across borders and between disciplines. It will also require new understanding between scientists, policy makers and citizens.

This represents a clear challenge to policy makers, scientists and the public as a whole that is passed on to educators thinking about the demands that are facing future citizens. Not only do they have to find ways of educating future citizens and scientists to meet such demands, but a certain creative effort also has to go into imagining what these challenges might be. How can we prepare young people to negotiate the relationship between science and citizenship in the 21st century when we struggle to understand its relationship in the 20th? As the futurologists of education are fond of pointing out, we are educating for a world where 50 per cent of the jobs today's primary school children will do have not been invented yet. However, these are the questions that creative science educators are dealing with on a daily basis and it is with these questions that the authors in this book are grappling with either explicitly or implicitly.

The territory is complex. Just as the relationship between science and society is shifting, so notions of citizenship in most parts of the world are contested. In much of the West, there are strong traditions, reaching back to the Enlightenment, of citizenship as a set of rights of the individual embodied in the institutions of the nation-state. This conception, in its British post-World War II context, was succinctly and influentially described by the sociologist T H Marshall (1950). He traced back civil, political and social rights to their origins in the struggles of the 18th, 19th and 20th centuries and related them to the structures and provisions of postwar European social democracies with their independent legal systems, universal suffrage and developing welfare states. Parallel to this liberal tradition of thought run other, often competing, traditions based on collective belonging. Within communitarian thinking, group rights may take precedence over the rights of individual group members. Tensions between these ways of thinking arise frequently where the liberal precepts of the state, for instance around equal rights for all citizens, run counter to group restrictions on certain behaviours. Whether this results in conflict

between the state and minority ethnic groups or between the state and supranational religious identities, loyalties of the citizen can be divided. Science frequently throws up such dilemmas. Government might deem the right to reproduction to be a universal one, or universal enough to provide IVF treatment through the welfare state. However, some religious groups might forbid its uptake by members on doctrinal grounds.

In addition to its contested context, in the 50 years since Marshall's work, the picture he painted has been complicated in many ways, not just by the influence of other traditions of political thought, but also in terms of the everyday experience of the citizen. In addition to concerns around climate change there is the acceleration in the development of communications technologies. We can now travel more, further and faster, have access to huge amounts of information and live within an endless torrent of media. While technological progress and increasing globalisation have touched most people's lives, they do not seem to have eliminated inequalities. The potential for global travel may be there and mass migration is a huge factor in creating the dynamic nature of the world we live in, but freedom of movement is seriously unequal, restricted to many without the right citizenship status. Communications technologies are spreading rapidly but are not available to all and the ubiquitous media can be as homogenising and as dismissive of diversity as they can be educational and empowering. Our understanding of citizenship must cope with an ever-changing context in which new arenas for the possession of rights are proliferating. In Marshall's day, rights had a past and a present but now we think more and more about their future. We have to address serious issues about the rights of the unborn child and where they start. We also have to look further ahead when considering the rights of future generations in relation to the environment. This proliferation of rights draws ever more attention to the unevenness of their possession. If a citizen of Japan born in 2004 is entitled to expect to live to 82, why is a citizen of Swaziland

born in the same year only entitled to expect to live to 37?[1] This changing context is often explained in terms of an experience of a world compressed in space and time (Harvey). Just as future citizens will have to think across spatial, national and disciplinary boundaries, they will also need to think back into the past and forward into the future with a degree of flexibility and creativity. In response to this changing social and political climate, many activists and theorists are looking to conceptualise citizenship less as a set of rights and institutions and more as a set of practices. Melissa Leach and Ian Scoones, writing from the interdisciplinary perspective of science and development studies, have formulated a useful conception of citizenship that seems to encapsulate this idea as "practised engagement through emergent social solidarities" (Leach, 2005, p. 31).

In these challenging times, there are some welcome initiatives, such as the Intergovernmental Panel on Climate Change, that enable scientific experts to engage with each across national boundaries and form new social solidarities. However, what fora for engagement with scientific ideas are available to citizens outside the scientific community? How can members of the public develop solidarities with scientific experts? How might educators prepare young people for a citizenship that does not just include the passive retention of rights and an ability to navigate the institutions of the nation-state, but also encompasses citizenship as practical engagement? This is particularly crucial in relation to science, where the implications are rarely confined within national borders and where the perception is often that state institutions struggle to keep up with the pace of progress. How might one 'practise the practice' of citizenship in a safe space but with a strong sense of a connection to real-world problems? This is clearly a challenge but one to which many of the practices dealt with in this book have risen.

The Pulse projects provided opportunities for practical encounters with scientific aspects of citizenship, through what the Pulse

evaluation describes as the creation of "cognitive and emotional dissonances" (Wellcome Trust, 2006). This creative process often incorporates the entwining of personal and scientific narratives. To take one example, artists from Stan's Cafe Theatre Company worked with science teachers and young people to create performance installations illustrating the impact of epidemics and vaccination on global populations. The creative educational intervention was the idea to use rice to represent people (one grain = one person). The opportunity for collective, creative participation lay in the young people's decisions on which statistics to use and how to juxtapose them for emotional impact. The science learning lay around developing an understanding of vaccination, research skills, the use of data and evidence. One of the young participants tried to explain the impact:

> Usually you'd see a statistic in numbers and it'd look big and you might think, oh yeah, that's quite a lot of people but when you actually see you think, it's a lot of people, it really sinks in, it really brings out a lot of feeling towards the people there, it's like seeing the people really…when you see the finished mounds of rice and you know that you've weighed it out, so you know it's really accurate then it's really in a way it's unbelievable, you know it's true but you just can't believe it when you actually see it yourself. (Wellcome Trust, 2006, p. 34)

This sense of wonder and the redefinition of the young people's learning spaces is not citizenship in the sense of an individualised exercise of rights or a relationship to a national political entity, but something much closer to citizenship as practical engagement.

If we are to work towards an education that will equip young people as the global scientific citizens or citizen scientists that Rotblat envisioned in order to meet global scientific challenges, it seems we must work together to search for the right interventions entwining a creative approach to science with an equally creative conception

Left:
Schoolchildren in Stan's Cafe Theatre Company's Plague Nation project, funded under the Wellcome Trust's Pulse scheme.

of citizenship. As hard as this may sound, in a keynote speech in 2002 on the relevance of science to citizenship education, Rotblat, at that stage into his 90s, was still not downhearted about the potential of educators and others to do this. As he asserted:

> Just as advances in science have made world citizenship an urgent necessity, they have also made it achievable. (Wellcome Trust, 2002)

The practices discussed in this book suggest that it is a task best undertaken by creative educators from all disciplines working together. Whether it is artists working with science teachers, drama teachers working with scientists or young people working with adults, it is the emergence of social solidarities across disciplines and boundaries of all types that gives us some grounds for sharing Rotblat's optimism as well as his vision. What approach to creativity can encapsulate such aspirations?

### Encountering creativity

Within recent debates sparked by the resurgence of interest in creativity, it is difficult to find anyone involved in education who advocates uncreative learning. Investigations into creative learning have stressed that creativity flows through all walks of life and all domains of knowledge and, far from remaining the preserve of the arts and humanities, creativity is now regularly associated with the sciences, mathematics, engineering, economics and management. In part, this renewed interest in creativity across the Western world is due to changing economic circumstances in post-industrial societies. The creative industries have become increasingly valued not only for their contribution to cultural life but also for their ability to generate wealth, and a new knowledge-based economy requires employees to be creative, innovative and flexible. With the notable exception of the euphemistic 'creative' accountancy, creativity is widely thought to make a positive contribution to contemporary society, promising a unique

combination of personal fulfilment, job satisfaction and economic prosperity. It is unsurprising, therefore, that in a political climate where organisations and industries are relying on creativity for their ability to compete in a global market place, encouraging or 'nurturing' creativity is becoming increasingly central to educational policies and practice.[2]

Whatever the motivations for this renewed interest in creativity may be, and however variously the term is interpreted, explorations into creative learning offer a timely opportunity to reconceptualise the relationship between the arts and sciences. Traditional oppositions between the sciences (objective, factual and impartial) and the arts (subjective, spontaneous and intuitive) seem increasingly redundant, together with stereotypical images of the scientist as a mad, white-coated and bespectacled man and the artist as an eccentric or isolated melancholic. Where such conventional oppositions between the arts and sciences are maintained, it might be expected that collaborations between them would emphasise the role of the arts to exercise a much-needed humanising influence on the arid factuality of science. In this conceptualisation, beauty is the sole preserve of the arts, and the sciences remain remote from the flimsiness of aesthetic judgements and the emotional distractions of empathy. If, however, both the sciences and the arts can make claims to creative thinking and learning, questions might be raised about how learning in the sciences is aided by intuition and moments of insight, and how the processes of working in the arts might make stronger claims for forms of investigation that are rigorous and methodical.

Reconfiguring the relationship between the arts and sciences, and offering ways to think about creative encounters between them, requires reflection on the creative processes that accompany these different modes of practice and contrasting ways of seeing. Creative juxtapositions between the arts and sciences provide young people

with the opportunity to question their own ways of learning. Throughout this book it is noticeable that artists and scientists use similar vocabularies to describe their working practices: both talk of experimenting, risk-taking, testing, interpreting, observing and investigating as integral to their methodologies. Furthermore, many contributors comment on the emotional impulses that motivate their work, and how their sense of wonderment and enthusiasm for exploring particular aspects of science has captured the imaginations of young people in collaborative projects with artists.

While the language that is associated with creativity and creative approaches to learning is often associated with the emotions, there is, of course, no guarantee that well-motivated and inspired young people who are actively absorbed in experiments are working creatively. Not only has creativity been theorised from a range of perspectives, including sociology, psychology, education and philosophy; the rhetoric of creativity has been assimilated into policies where its meanings are often vague or oversimplified.[3] Often conflated with individual talent, some theories of creativity have tended to emphasise specific personality traits, or point to particular modes of behaviour. The work of the psychologist Mihaly Csikszentmihalyi offers a good explanation of this way of thinking. In his influential study of creativity, he outlines a generalised theory of creativity, which, while it takes some account of cultural and societal influences, is based on an assessment of personality traits. He describes creative individuals as more complex than 'normal' people because they are able to hold simultaneously apparently paradoxical qualities; he includes realism and imagination, humility and pride as examples of such conflicting impulses (1997, pp. 55–76). He identifies ten "antithetical traits" that he observes in all creative individuals, and his challenge to the dialectic between the arts and sciences is based on this premise: "when a person starts to work creatively…the artist may be as much of a realist as the physicist, and the physicist as imaginative as the

artist" (p. 64). According to Csikszentmihalyi, although some personalities have a strong disposition towards creativity, it can be cultivated in the more ordinary activities of everyday life if people are prepared to modify their behaviour by breaking with routine, thereby "liberating" their "creative energies" (p. 344). In such behaviourist conceptualisations of creativity, personal freedom and creativity are assumed to be coterminous and formal education is often thought to stifle originality.

Creativity, according to theoretical models that measure behaviour and personality, has been codified as a five-stage process. It begins with a period of preparation, moves through an incubation phase, insights are then generated (sometimes called the inspirational 'Aha!' moment) after which follows a period of evaluation. The final phase is elaboration, a period during which ideas are translated into tangible forms. While broadly accepting these components, Csikszentmihalyi warns against linearity, arguing that the creative process is often more recursive and circular than this model implies (1997, pp. 79–80). For artists, teachers and scientists involved in developing young people's creativity, this model can provide a helpful way to recognise the different phases the work might undergo, and it can offer ways to structure the learning process. In practical terms, creative learning is likely to be found in classrooms where children are encouraged to combine their subject knowledge with personal experience, and when they are given time to reflect on their learning as well as to generate ideas. Constructing this learning environment requires planning for different phases of the creative process; it suggests that young people's creativity is supported when teachers put structures in place.

The limitation of Csikszentmihalyi's model, however, lies less in its codification of the creative process, and more in the ways it both individualises creativity and assumes that such generalised patterns of creative behaviour can be transferred across all areas of human activity. Those who take risks, think divergently, make

connections, ask questions, solve problems and so on are widely regarded as creative, although the relationship between creativity and collaboration has been overlooked or misunderstood. The individualisation of creativity chimes well with a target-driven education system, and it is noticeable that students' achievements are often measured according to specific predetermined indicators.[4] Sometimes young people are asked to evaluate their own creative processes according to criteria that emphasise their private, inner thoughts rather than collaboration and discussion. A good example of this way of thinking about creativity is a framework that is currently promoted by Creative Partnerships' Creativity Wheel, where all statements for children's self-evaluation begin with the word 'I'. Examples include:

I can create things in my mind.
I can see more than one way of looking at things.
I can think of unusual ways of doing things.
I can see if my work has a purpose.

This emphasis on the first-person pronoun seems to negate the significance of collaboration in the creative classroom. Of course, sometimes creative practice is highly individual, but more often creativity in both the arts and sciences involves a complex process of collaboration, where it is forgotten where the idea came from and unnecessarily competitive to remember who had an idea first.

The collaborations between artists and scientists discussed in this book suggest that individualised models of creativity are ripe for revision. Although educationalists have recognised the importance of domain-specific knowledge and skills to creative processes, one of the recurring themes in accounts of practice discussed in this book is the relationship between innovation, history and society. In their chapter on chimeras and genetic hybrids, Elio Caccavale and Michael Reiss show how collaboration between artists and scientists has the potential to create new domains of knowledge,

not only in response to scientific progress, but also as a way of asking moral questions about the future of society. By inviting young people to make decisions, they are able to integrate their knowledge about science with their understanding of the role of the arts. This draws attention to the pace of social change, and recognises that both the arts and sciences are responsive to their contemporary contexts and have the potential to have an impact on the future.

Social psychologist Robert Weisberg argues that creativity is a context-specific process, supported by social networks and cultural geographies. He cites Watson and Crick's discovery of the structure of the DNA molecule as a good example of the impact of situation and setting. Watson and Crick came from different scientific backgrounds, allowing them to see the problem from different perspectives and, Weisberg argues, their methods of working were incremental and collaborative rather than reliant on flashes of inspiration. Watson and Crick were not the only scientists working on DNA in the 1950s and, had the setting and circumstances of their investigations been different, other scientists would have undoubtedly made the discovery. Using this case study as evidence, Weisberg builds his theory of creativity on systems and material conditions rather than on individual personality or patterns of behaviour (1986, pp. 91–98).

It is evident in the partnerships between scientists and artists documented in this book that there is a creative space to be found where experts in both fields work at the edge of their conceptual understanding. Chris Bilton, writing about the management of creativity, argues that creativity flourishes when people from different or divergent perspectives are brought together to investigate a shared problem or question. Bilton recognises the impact of individual spontaneity and insight, but also suggests that the composition of groups or teams is integral to creative learning and thinking. Rather than ascribing roles to individual team

members based on psychometric tests, learning styles or different forms of intelligence that are often difficult to break once acquired, he proposes that creativity is based on a flexible balance between specialist expertise and a shared understanding of the problem or brief. "Innovative thinking", Bilton argues, "requires a dialectical process, challenging assumptions from one frame of reference by layering in criticisms from another" (2007, p. 35).

Encounters between scientists and artists are particularly creative when interactions between the two areas of study and practice are allowed to inform and shape each other. The evaluation of the Pulse projects in 2006 provides a good example of how one discipline is altered and reconstructed by its encounter with another:

> The participatory arts were shown both to **facilitate** the communication of science and to **reconstruct** science as a set of open, adventurous, inclusive, alive, enjoyable and dynamic processes, with relevant (inspiring, shocking, emotive) concepts about the world. (Wellcome Trust, 2006, p. 8)

The ability to move productively and dynamically across disciplinary and conceptual limits is facilitated, according to Bilton, by the imposition of constraints and boundaries. Contemporary creativity theory has rejected the idea that freedom from external constraints provides the best conditions for creative collaborations, recognising instead that creativity is as dependent on rule-making as it is on rule-breaking. The argument is summarised by Bilton:

> Creative thinkers understand and acknowledge the context in which they are working, and recognise the constraints imposed by genre, technique and tradition. Having recognised these constraints, they push up against the limits of the possible, testing the boundaries of the field from the inside out. The moment of transformation comes not from thinking outside

> the box but from rethinking and redefining the shape of the box from within. (2007, p. 77)

Applied to collaborations between science and the arts, this systemic theory of creativity implies that the synthesis of ideas is dependent on an understanding of differentiated expertise and a willingness to test boundaries and make new rules. This way of thinking about creativity effectively breaks the perception that scientific knowledge is fixed and unerringly authoritative, and promises to both disturb the restrictions of patterns of thought and open new possibilities for meaning-making.

There is no particular obstacle as to why such a way of thinking should not be applied to practice in schools as well as other arenas of arts–science collaborations. From this perspective we can now put certain accepted pedagogical practices under the spotlight. In training for teachers in secondary schools, at least in the one-year courses for graduates, pre-service teachers focus mainly on their subject. There is therefore little opportunity for those new to the teaching profession to engage in interdisciplinary discourses and explore problems together. Yet, in a multidisciplinary science such a narrow focus risks being out of kilter with the contemporary world. In an article on the use of evidence by professionals, Glen Aikenhead (2005) demonstrates how nurses use happiness, emotion, feelings as data sources to make judgements. Thus, they can tell how a patient is responding to treatment by changes in disposition, whether they are happier or more comfortable. The point here is that understanding evidence has broad connotations. In the context of a science lesson it might suggest accuracy and reliability of scientific measuring instruments such as thermometers, for a historian evidence relates to the accuracy of sources from texts, for an RE teacher it might be evidence from a particular ethical position, for an English teacher the way an idea is represented in diverse media. But it is more than this. As the quote from Stan's Cafe so potently shows, it was the impact of the

mounds of rice that turned numbers into a sense of social justice. Unless teachers collaborate in an interdisciplinary way it becomes difficult to test those ideas, so prevalent in contemporary science, that extend beyond their own domains.

### Creative futures

The present is perhaps best understood through the narratives of history, and in this introduction we have sought to contextualise popular perceptions of sciences and the arts in order to challenge them. Locating abstract thought as well as more material inventions and discoveries within their historical contexts enables us to better imagine the future, or at least to acknowledge what is unimaginable. The arts and the sciences have always upheld established modes of thought as well as providing ways to subvert authority and create social change. It is precisely because there is no guarantee that either mode of inquiry will contribute to creating a just society that education should engage young people in ethical questions about how they will define their roles as citizens.

One of the recurring themes in this book is that we are defined ethically by our interactions with others. This means that finding the creative space that links together the sciences and the arts is inherently a social practice, dependent on children working together and developing mutual understandings. If creative encounters between the arts and sciences are to be both playful and rigorous, they will not dissolve the parameters of each, but they will inspire curiosity by gathering insights from different perspectives. The sciences and the arts, as necessary partners, will create new spaces for wonderment and contexts for questioning and telling stories.

1 WHO, 2006, Annex Table 1.

2 The phrase 'nurturing creativity' is used by a Department for Culture, Media and Sport report written by Paul Roberts (2006) to inform policy on creativity and young people. The phrase implies that creativity is innate, and underlines the significance of preparing young people to participate in a creative economy.

3 See Banaji and Burn (2006).

4 An example of this way of thinking about creative individuals in education might be found in the Qualifications and Curriculum Authority document, *Creativity: Find it, promote it* (2003) that defines four characteristics of creativity.

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