Mathematics, science and the liberating beauty of theatre

Joe Winston

Beauty is a concept more usually associated with the arts than the sciences. Yet many scientists and mathematicians perceive beauty in the phenomena they study. This beauty, notes *Joe Winston*, is not an aesthetic judgement but a deep emotional and inspirational experience. Among other things, it can inspire learning. Incorporating this experience into the teaching and testing routines of modern science education is not straightforward, yet failing to acknowledge the importance of beauty threatens to marginalise an experience that should be central to children's learning.

Introduction

It is nothing controversial to argue that current educational thinking, in policy and practice, is dominated by the languages of target-setting, performance management, skills acquisition and quantifiable assessment criteria. Behind this lies a belief that only what can be measured, or demonstrated clearly, or backed up by facts can be trusted; and in an age of increasing global economic competitiveness, certainties about increased performance and rising standards are seen as necessary in order to ensure future prosperity. The resultant rhetoric – of improvement, efficiency gains and best practice – may well, as Onora O'Neill has argued, sound admirable enough but beneath it "the real focus is on performance indicators chosen for ease of measurement and control rather than because they measure quality of performance accurately". (2002, p. 54). The danger, then, is that those more elusive qualities that education may legitimately concern itself with can become sidelined or ignored. In such a climate, it is small wonder that the concept of beauty should be relatively unheard-of in educational discourse, especially within the disciplines of maths and science. Despite the fact that statements about the uncertainty of science can be found in most national examination specifications in the UK, there is still a 'common-sense' view among teachers, influenced by the dominant educational ideology, that these subjects deal in the kind of certainties best suited to clear and transparent objectives-based teaching. This chapter will, however, propose that the more elusive qualities of beauty have a place in their teaching; and that to ignore this is to fail to appreciate the power of beauty to motivate a desire to learn.

Above:
Scene from *A Disappearing Number*.
Joris-Jan Bos

Learning from *A Disappearing Number*

Numbers are pervasively significant in the contemporary world. Through clocks, mobile phones, prices, weights, bus and train timetables, TV and radio channels, account numbers, paycheques, they regulate and order our daily lives. In schools they provide the quantitative data of test scores and percentiles used to measure attainment and verify accountability. The power and nature of numbers was, however, explored very differently in a recent play, *A Disappearing Number*, conceived and directed by Simon McBurney and performed by Theatre Complicité.[1] The piece was experimental in form, crossing time and space, telling parallel and interrelated stories that centred upon the lives of two mathematicians. One of these is Srinivasa Ramanujan, the mathematical genius, who moved from a job in a clerk's office in India to work at Cambridge University during World War I, before dying tragically young. A similar untimely death befalls the fictional character, Sarah, a university lecturer, whose research focus is the work of Ramanujan. The principal character, however, is very much a non-mathematician called Alex. The play opens in the form of a maths lecture, where Sarah introduces the formula of a complex equation developed by Ramanujan, whose proposition ($1 + 2 + 3 + 4 \ldots \infty = -\frac{1}{2}$) seems incomprehensible, absurd even, to the average member of the audience. This is also where Alex meets her for the first time, starting a process for him that begins as a love affair but becomes a quest for understanding; for the more he grows to love Sarah, the more he needs to understand what it is that drives her passion for her subject. Their story is told episodically, and Sarah's fascination parallels that of the historical figure G H Hardy,

Theatre is an ephemeral art form, the most impermanent of all, like our lives, existing only in space and time.

author of *A Mathematician's Apology*, who invited Ramanujan to lecture in Cambridge. If the progression of the play finds its dynamic in both Alex's and Sarah's quests for understanding, its artfulness stems from McBurney's parallel fascination with the mysterious power of numbers and his attempt to realise in theatrical form the beauty of the mathematical concepts that connect the characters' lives. A hint to this is provided on a photograph in the programme notes. McBurney is shown in front of a blackboard, at the centre of which he has written the word 'beauty'. Along a horizontal axis, this is connected to a mathematical equation through the words 'constancy', 'performance', 'certainty'; the vertical axis sees it connected to the human world, which includes the words 'uncertainty' and 'imagination', and also 'theatre'.

The play engages these two ideas of beauty – the ideal and the material – in a dance between the mathematical concepts at its core and the aesthetics of theatre that give them expression. Key among these is the theory that everything is interconnected through time and space through numbers, an idea that goes back at least as far as Pythagoras and has resurfaced more recently as an element of string theory.[2] One of the play's key symbols is patterned through the classical Indian music and dance that permeate its formal structure, relating Ramanujan and a series of minor characters to their cultural roots through an art form that depends heavily on vocal rhythmic counting, rooting art and number to a sense of cultural and historical tradition. Around this illusion of constancy, the material reality of the stage space is continually and visibly transformed to denote shifts in time, as in a scene that begins with Sarah delivering a lecture on Ramanujan's work. While she does this, we see the actor playing the part of Hardy take up a position directly behind her. As she quotes from a lecture he gave in the 1920s, he begins to speak with her, then continues the lecture on his own, relocating the audience in historical time as the actor playing Sarah leaves the stage.

Crispin Sartwell has suggested that beauty matters so much to us because it captures our longing for permanence; in his words: "Beauty is the string of connection between a finite creature and a time-bound world" (2004, p. 150). This tension between the finite and the infinite is encapsulated neatly in two scenes; once through a discussion of what is often referred to as Zeno's second paradox – that $1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \frac{1}{16} + \frac{1}{32}$ etc. will eventually make two but only an infinite two[3] – then in the final scene, where Alex visits Sarah's grave. There he holds a piece of chalk, found in her trunk, identical to the chalk she held when he first met her, the chalk with which she wrote the mathematical equations that left her trace on the world. As he stands there, ashes and sand – or is it powdered chalk? – begin to pour over the stage, an image of death and of time running out. This is accompanied by the sound of a number pattern being repeated and repeated, gradually fading. Theatre is an ephemeral art form, the most impermanent of all, like our lives, existing only in space and time. When the chalk/sand/ashes cease to fall, the lights dim and the play is over; but the numbers keep repeating, ever fainter yet still distinct; for a while at least, through the illusion of theatre, it seems that they will continue to be repeated infinitely.

What I have called somewhat grandly "the liberating beauty of theatre" could equally be called in this instance "the liberating beauty of mathematics", capturing as it does a personal response to this particular play. *A Disappearing Number* reminded me that numbers need not only be used to quantify, order and control our lives but that they are also mysterious and fascinating. The truths they promise can be elusive, paradoxical and play tricks on our human rationality. Above all, they can be sources of wonder and this is at the heart of what John Armstrong (2005) has called "the secret power of beauty".

Learning through beauty in science education

> For some people the contemplation of scientific theories is an experience hardly less golden than the experience of being in love or looking at a sunset. (Haldane, cited in Mark Girod, 2006, p. 47)

Beauty is not something we need to look up in a dictionary to understand. It is a word common to all of us and, although we may not all find the same things beautiful, we understand each other quite readily enough when we use the word. The philosophers of ancient Greece were very clear about beauty, what it meant and how central it was as a human value. Aristotle postulated that to find something beautiful was to find in it a quality of excellence that kindled an emotion akin to love; we can locate this meaning in common usage today when people talk about a beautiful tune, a beautiful dress, a beautiful smile. Plato had a lot to say about beauty, too, some of which might be less evident to modern sensibilities. In works such as *Phaedrus* and the *Symposium* he constructed an argument that linked it essentially with *eros* – with pleasure, passion and desire – in which the longing inspired by beauty was intimately connected to a longing for goodness and truth. As Nehamas explains, for Plato:

> ...all beautiful things draw us beyond themselves, leading us to recognize and love other, more precious beauties, culminating in the love of beauty itself and the happy life of philosophy. (2007, p. 6)

Even at its highest, most idealised form, however, "beauty cannot be sundered from understanding or desire. The most abstract and intellectual beauty provokes the urge to possess it no less than the most sensual inspires the passion to come to know it better" (ibid., p. 7). This account of the cognitive energy of beauty is very much in line with Alex's experience in *A Disappearing Number*. He begins by desiring Sarah, in whom he finds beauty, just as we find

beauty in anyone we love. But his desire does not stop with possessing her physically. He wishes to understand her, which means he wishes to understand what she understands, appreciate what she loves.

> Beautiful things direct our attention to everything else we must learn and acquire to understand and possess them and they quicken the sense of life, giving it new sense and direction. (ibid., p. 76)

In the play, Alex remains perplexed, as he lacks the mathematical grounding to begin to make sense of the complexity of it all. But along the way he learns and makes inroads, as we do, and at least comes to understand how and why Sarah is in thrall to mathematics: not because of its potential applications or its practical uses but because of its beauty. As Dirac once famously said: "It is more important to have beauty in one's equations than to have them fit the experiment" (cited in Girod, p. 40). This is what provides her learning with its future-oriented dynamic, what drives her to want to understand more. Nothing is ever settled and her desire to carry on learning, to know better, continues. This passionate quest to learn inspired by beauty is summed up in the words of Elaine Scarry:

> The beautiful, almost without any effort of our own, acquaints us with the mental event of conviction, and so pleasurable a mental state is this, that ever afterwards one is willing to labor, struggle, wrestle with the world to locate enduring sources of conviction – to locate what is true. (2001, p. 31)

Small wonder that she goes on to state that "beauty is a starting place for education". But such a starting place has little in common with the currently dominant objectives-based approach that concentrates on quantifying and measuring whether something has been learned or not. This does not energise a desire or longing to learn, a point wryly made by the following true story:

If we relate the objectives approach directly to science, we can see that its technicism ignores the deeper mysteries and wonders that have inspired the many genuine scientists with a passion for their subject.

> An eight-year-old boy…was asked 'Do you think you ought to learn to read?' Having answered in the affirmative, he was then asked, 'Why do you think you should?' to which the reply was 'Then I can stop', a response that might have been thought of, even though not expressed, by many less honest pupils! (Arnold, 1982, p. 16)

Achievable objectives do of course have their place in education and there are those elements of learning that are factual and necessary that can be usefully and visibly assessed. But these are small steps inside a much wider context. They are not in themselves purposeful and attaining them does not generate satisfaction for the learner beyond any immediate sense of mastery. If we relate the objectives approach directly to science, we can see that its technicism ignores the deeper mysteries and wonders that have inspired the many genuine scientists with a passion for their subject, a desire to make sense of what they do not yet understand. As Girod has pointed out:

> Often in the retelling of a scientific discovery the 'human', 'creative', 'inspired' and 'passionate' sides of scientists and their stories get left out. These are often deemed unimportant or anti-intellectual, pulling readers away from the important details of theory development, research results and solutions to equations. (2006, p. 39)

This omission is due to a pervasive belief that science, like maths, is a world of paradigms, models and laws, of pure reason, above and beyond the human world of narrative and metaphor, art and emotion. Yet maths and science are alive with symbols and, as Kuhn has taught us, have their own historical narratives within which they locate their arguments and develop their theories. And these, as the quotation from Dirac above reminds us, are guided by the human delight in beauty as well as truth. "It was aesthetics and not observation that refuted Ptolemy and led to Copernicus"

(Sartwell, 2004, p. 20) – Sartwell's claim is provocatively partial but his point is nonetheless profound. Ptolemy's cosmology may well have accounted for what astronomers were able to observe, but its narrative of cycles, epicycles and epiepicycles lacked the simple elegance of Copernicus's heliocentric explanation for the same observations.

In Girod's recent work on the place of beauty in science and in science education, he is much influenced by John Dewey. As Nehamas recognises with the Platonic tradition of beauty, so Girod recognises with Dewey's account of aesthetic experience – that Dewey reintroduces this experience into the common language of the everyday, democratising it as a condition of living in the world rather than as something pertaining only to art houses and museums. Girod usefully summarises what Dewey sees as the conditions characteristic of having an experience as distinct from the common flow of experience typical of everyday living:

> An experience is contrasted with ordinary experience and is identified as having a series of qualities including (1) the fusing or intermingling of thought, emotion and action; (2) the expansion of one's perception literally creating new ways of seeing the world, and; (3) an increased feeling of value for this newfound perspective. The process of having *an* experience typically unfolds through a transaction between the person and world in which each emerges as different than before the experience. (2006, p. 48)

This definition helps us see that beauty's role in science education can best be grasped in terms of the experiences it can provide, rather than through the targets and outcomes that science in schools has all too often been reduced to. It also presents beauty's energies as cognitive as well as sensory, and transformative rather than cumulative. In other words, an apprehension of beauty can change students' perceptions dramatically, allowing them to grasp

All of these activities can help children wonder at the beauty of colour and light and, by sharing in their curiosity and excitement, teachers can help lay a foundation for the conceptual knowledge that later years can build upon.

the error or ignorance of their previous, common-sense understandings. I am not suggesting that teachers who work within the framework of the National Curriculum cannot provide learning experiences of this kind but that it requires a vision that looks beyond the prescribed learning outcomes.

"Science is replete with powerful ideas that have the potential to lead us into Deweyian experiences if we are open to them and allow them to unfold," writes Girod (p. 50). This is a comment interestingly reminiscent of the words of the art critic, Michael Kimmelman, who wrote about beauty being "out there waiting to be captured, the only question being whether we are prepared to recognize it" (2005, p. 5) and is something that foundation-stage/early-years teachers can readily convey to their pupils in topics such as light and colour. Children can investigate prisms and then create their own by pouring oil on top of a plate of water; they can shine torches on mirrors or through coloured gels in a 'dark cave' created by blacking out the home corner; they can mix colours with powder paint; make their own spinning circles to see how colours merge to create new colours; and make simple kaleidoscopes from card, plastic mirrors and coloured beads. All of these activities can help children wonder at the beauty of colour and light and, by sharing in their curiosity and excitement, teachers can help lay a foundation for the conceptual knowledge that later years can build upon.

Pugh and Girod outline a pedagogy, based on their own research, intended to move towards what they call a "transformative, aesthetic science education". The principles that underlie this are listed below (2007, p.14) with my own summaries of their lengthy explanations in italics:

Methods of crafting ideas out of concepts

(ideas about how to transform ordinary concepts into compelling ideas that will lead students to see and experience the world in a new way)

- Restore concepts to the experience in which they had their origin and significance: *help students understand the power these concepts had when first discovered by placing them in a clear historical context*.
- Foster anticipation and a vital, personal experiencing: *treat the lesson as a dramatist would treat a plot, choosing the elements of content that are most vital and crafting them together to create maximum anticipation and personal involvement*.
- Use metaphors and re-seeing to expand perception: *helping us see things anew by breaking routine, making us see the commonplace afresh or making the extraordinary apprehensible*.

Modelling and scaffolding a transformative, aesthetic experience

(ideas of how to enculturate students into ways of valuing and experiencing science ideas)

- Model a passion for the content: *the teacher fosters and demonstrates their passion for science*.
- Scaffolding students' action, perception and valuing: *help students into deeper levels of understanding by providing experiences that move them, for example, from a peripheral to a more central participation*.

The sample of activities on light and colour outlined above provide ready opportunities for teachers to model passion and scaffold learning in the manner proposed in the final two points. If we turn our attention to older learners, Clive Sutton gives some excellent examples of how scientists responsible for major discoveries had to struggle with language and find the right metaphors in order to help others enter imaginatively into their new ways of seeing (1992, p. 41). Harvey's choice of the metaphor of a pump for the heart, for

Children have a strong desire to ensure that their methodology is fair and thorough and, of course, an 'expert' is on hand to support the scientific thinking and processes.

example, or Robert Hooke's use of the word 'cell' to describe the millions of little cavities he saw in a slice of cork placed under a microscope: both are examples of scientific language arising from excitement and amazement, guided by aesthetic and interpretive choices to capture meaning in language that has since become conventional. A good example provided by Sutton as to how children might recapture this sense of wonder through metaphor relates to Torricelli's realisation in the 19th century that the atmosphere we live in is essentially an "ocean of air". By being introduced to a passage written in 1878 by Arabella Buckley, children can be invited to imagine a being "whose eyes are so made that he could see gases as we see liquids" and to respond to what they imagine this being would see (Sutton, ibid., p. 41).

An example of a lesson planned as an unfolding story, as a dramatic plot guided by the teacher, is provided in a scheme for Key Stage 2 teachers by Linda Atherton, primary science adviser for Warwickshire Educational Development Services. Entering the classroom, the children find their desks moved back and the outline of a corpse chalked on the floor. They are informed by the teacher (in role as a forensic scientist) that there has been a murder for which there are four suspects, whose details are provided on a worksheet. There are also various pieces of evidence near the body, including samples of fabric, powder and a muddy footprint. Children search for clues in order to correlate data already collected and are then asked to interrogate the evidence, make links and detect patterns in a systematic, safe and fair way as it will be presented to a prosecution lawyer to see if there is enough of it to take to court. This is where the activity explores key scientific processes and ideas. Filtering, for example, is a technique that now has a real purpose in order to identify the soils; the white powder samples react in very different ways and allow for discussion of reversible and irreversible reactions; looking at fibres under a digital microscope, the children explore the differences between those that are natural and those man-made. Once children realise the

relationship between size of feet and height, they can confidently use this information to predict the height of someone at the scene. Group talk becomes clearly focused on scientific principles and tables are produced to collate evidence. Children have a strong desire to ensure that their methodology is fair and thorough and, of course, an 'expert' is on hand to support the scientific thinking and processes. The courtroom is then set up with the teacher in a new role as prosecutor, asking tough questions about whether and to what extent the evidence incriminates any of the suspects, thus forcing children to re-evaluate what exactly it is telling them and how valid their interpretations have been.

This model of lesson planning approaches the aesthetic experience of theatre and I would like to conclude by looking at two theatrical productions, conceived and developed for children of five years of age and under, one of which was funded by the Wellcome Trust. In doing this, we can examine how mathematical and scientific ideas and applications can be introduced to stimulate very young children's imaginations and cognition through the means of theatre and the power of beauty, to leave them not with any definable learning objectives but something more elusive yet more potent – a sense of fascination and wonder.

Young children experiencing science and beauty through theatre

Theatre-Rites is commonly regarded as one of the foremost and certainly one of the most innovative children's theatre companies currently operating in the UK, specialising in work for audiences of young schoolchildren and pre-school children with their parents. Their performances are characterised by their highly visual quality and their use of multimedia technology to create work that I would describe as playful, striking, exhilarating and beautiful.

The Thought that Counts, which toured in 2007, deals with a range of scientific, mathematical and social issues by exploring the beauty

of the art form and ways it can fashion abstract concepts into memorable theatrical images. Its priority is to provide children with a striking aesthetic experience and, in doing this, it plays with the mathematical concepts of number and ordering, circles and spheres, volume, size and sequencing, with the scientific concepts of gravity and the solar system, and with social ideas such as friendship, separation, loneliness and togetherness. These are playfully realised with strong uses of coloured lighting, sound, music and multimedia, revealing the theatre as a place where anything can be created and explored. The aim is to inspire wonder and leave the children with plenty for their imaginations to dwell upon after the show has concluded. Such work, too, has a moral purpose: in the words of Roger Deldime, the French writer on theatre for children, *"c'est un porteur d'utopies, [qui] suggère que la vie peut et doit être changée, que l'impossible est possible"*[4] (1999, p. 16).

Above:
Scenes from *Hospitalworks*, co-produced with Polka Theatre and Theater der Welt.
Paul Tanner

Theatre-Rites's plays do not have a storyline as such but develop through a succession of scenes and images that progress logically from one to the other, principally through the narrative possibilities presented by their visual imagery. In *The Thought that Counts*, the images centred upon five actors, contrasting circles of light and a series of inflatable balloons, or spheres, of differing sizes. At different times these were thought bubbles held over one actor's head as he worried about speaking in public, carriers of different numbers projected on to them, balloons and balls that could be used to play games that would include or exclude different actors, balls that could be bounced on sequences of numbers that appeared and disappeared in a circle of light, planets of the solar system

rotated through the darkened space by the actors themselves, or a meteor charging at the surface of the moon. There was also a white, plastic puppet that appeared to self-inflate early on in the performance. During the central, rhythmically slower part of the play, the action focused upon her, as the stage darkened and transformed into a moonscape projected on to the floor. Music and actors all added to the spacewalk effect as they danced slowly over the surface, taking turns to guide the balloon creature and protect her from the attacking meteor. Such playful affects are not designed to teach children how to add up or explain how gravity or the solar system works, of course, but to help, in Sutton's terms, "develop their seeing ability" (1992, p. 40). The aesthetic charm and heightened sensory environment serve to anchor children's attention so that, hopefully, they will leave the theatre fascinated with what they have seen, with memories of planets as spherical objects moving slowly in circles around a larger sphere, and with a sense that walking on one of these worlds is not the same as walking on this one. Such wondering can form the foundations for scientific curiosity.

Above:
Scene from *The Thought that Counts*.
Robert Workman

In *The Thought that Counts*, children are drawn into an awe-inspiring journey through the solar system, where actors walk on the moon and, through the effects of multimedia technology, seem to disappear into giant spheres, sent spinning like space capsules through the darkness. Yet this is done with gentleness and humour and comes between the more domestic charm of scenes where actors play games with one another, where a fragile balloon person self-inflates and children are given their own balloons at the end of the performance as a delicate reminder of the journey they have been on together.

Theatre-Rites worked with Polka Theatre, another London-based company, funded by the Wellcome Trust, to produce a site-specific piece entitled *Hospitalworks* in 2005 and this, too, brought the lighter qualities of beauty – its charm and lively gaiety – into a

location normally known for more overwhelming associations of life and death. The event took place in a disused ward of the Mayday University Hospital in Croydon. The audience were led through some of the working parts of the hospital before reaching the performance space, which took the form of a magical ward, where the audience took on the role of visitors and the performers the role of staff in a hospital where the patients were, in fact, the everyday objects in the ward – beds, pillows, lamps. Staff performed the kind of routines of care that one would expect; to this extent, children could observe and learn what these routines consisted of. What made them memorable was the surprisingly playful ways in which they were enacted.[5] So, for example, a bed was examined and diagnosed as having a bad chest; a reluctant pillow puppet was given an injection; children were given sticking plasters to stick over cracks in a wall to help it get better; and they watched nurses assist as a bed gave birth to a pillow. Amid all of these essentially comic elements were woven moments of tenderness and moments of striking visual beauty. At one point, death was represented by a bed covered in colourful flowers being led slowly and silently through the ward. This contrasted with a scene where the newborn pillow was gently cradled and comforted with a lullaby. Part of the show consisted of a less structured, more interactive 'free-play' area where lighting and sound created atmospheric and colourful areas where children could listen with stethoscopes to a (mechanically) 'breathing' bed, be guided through a maze of drip bags hanging from the ceiling and bathed in multicoloured lighting, and use UV torches in an X-ray room to examine the skeletal structure of a hospital bed.

The work of Theatre-Rites is nothing if not openly and powerfully playful, and lest we dismiss play as relevant only to young children, we need to remember how it is not only at the core of theatre making but also, according to the philosopher Friedrich Schiller, both an essential human need and the spur to our creation and appreciation of beauty. He believed that humanity has two basic,

conflicting drives, those of sense and of reason. In denying either one superiority over the other, he proposed that a third drive – that of play – served, as something that we naturally enjoy, to keep both reason and sense in their rightful place. The object of play for Schiller is to unite in balance our desire for sensation with our desire for order; and the highest form that this can take, he believed, is in the form of beauty itself.[6] In both of these performance projects, *The Thought that Counts* and *Hospitalworks*, we can see this dance between order and sensation at the heart of their aesthetic; the ordered world of number, of the planetary system, of the applied science and routines of the hospital are playfully explored, disturbed and re-imagined within the heightened sensory environment of the theatrical spaces they created.

Conclusion

There are volumes of complex and difficult literature on beauty and aesthetic philosophy that I have largely avoided in this chapter, wishing to emphasise the immediacy of beauty, the instinctive pull it exerts upon us and those qualities capable of inspiring and motivating us to learn. Beauty is something that both adults and children can talk about and relate to readily and with pleasure. But, of course, we do find different things beautiful. As Kant put it: "there can be no rule by which someone could be compelled to acknowledge that something is beautiful" (1987, p .59). Although we can argue with some conviction that beauty itself is a universal human value, taste – what we actually find as beautiful – will vary according to culture, age, class, gender, the times we live in and a whole range of determinants that shape individual identities. Theatre, however, is a social event and theatre as joyful and celebratory as the two children's performances described here do, as Colin Counsell has argued, create a forceful draw towards consensus and conformity of response. In his words: "Theatre… provides a mechanism for group discipline and unified interpretation whose efficacy outstrips that of any other artform" (1996, p. 22). Actors perceive the audience just as the audience

The real value of such projects, I would argue, is what they teach us about the power of beauty to stimulate wonder in subjects whose disciplines of knowledge are often mistakenly blurred with the reductive agenda of skills-based learning.

perceives the actors, and in response can subtly modify and adapt their performance. In other words, the experience of beauty through theatre can become shared and powerfully communal. Some hint that this was indeed the case can be found, paradoxically perhaps, through the very quantifiable evaluatory procedures that are nowadays demanded as proof of educational value. Feedback from both family and school audiences for Hospitalworks showed that 65 per cent rated the show as excellent and 28 per cent as very good (beautiful not being one of the categories, of course). Such figures are doubtless heartening, particularly if they lead to further projects of this kind. But the real value of such projects, I would argue, is what they teach us about the power of beauty to stimulate wonder in subjects whose disciplines of knowledge are often mistakenly blurred with the reductive agenda of skills-based learning. Such an argument does, however, present a challenge to educationalists who specialise in theatre as much as those who specialise in science or mathematics. Despite the unavoidable demands to clarify learning objectives and quantify evaluatory procedures, there is a need to remain healthily sceptical of their limitations and not to be seduced by their false certainties. There can be nothing certain or resolved in any attempt to fashion or shape a beautiful experience, but to do so is a core purpose of art; both science and mathematics, to paraphrase the previous quote taken from Pugh and Girod, are replete with ideas and concepts that lend themselves to this purpose.

1 The play was performed at the Warwick Arts Centre at the end of April 2007.

2 See Aristotle's *Metaphysics* and http://superstringtheory.com.

3 See the essay 'Avatars of the Tortoise' in Borges (1970).

4 'it's a bringer of utopias, suggesting that life can and ought to be changed, that the impossible is possible' (my translation).

5 See Deldime and Pigeon (1988) to find support for this statement. The largest quantitative survey to date of the memories of young spectators discovered that surprising visual spectacle remained for longest in their minds.

6 For play as the basis of theatre see Schechner (2002), chapter 4; for a summary of Schiller's theory of beauty see Armstrong (2000), pp. 151–68.

Bilbiography

Armstrong J. The Intimate Philosophy of Art. London: Penguin; 2000.

Armstrong J. The Secret Power of Beauty. London: Penguin; 2005.

Arnold H. Listening to Children Reading. Sevenoaks: Hodder and Stoughton; 1982.

Borges JL. Labyrinths. Harmondsworth: Penguin; 1970.

Counsell C. Signs of Performance: An introduction to twentieth century theatre. London: Routledge; 1996.

Deldime R. Questions de Théâtre 6: D'une rive a l'autre. Brussels: Lansman; 1999.

Deldime R, Pigeon J. La Mémoire du Jeune Spectateur. Brussels: De Boeck; 1988.

Girod M. A conceptual overview of the role of beauty and aesthetics in science and science education. Studies in Science Education 2006;43:38–61.

Kant I. Critique of Judgment. Cambridge: Hackett; 1987 (transl. WS Pluhar).

Kimmelman M. The Accidental Masterpiece: On the art of life and vice-versa. New York: The Penguin Press; 2005.

Nehamas A. Only a Promise of Happiness: The place of Beauty in a world of Art. Princeton: Princeton University Press; 2007.

O'Neill O. A Question of Trust: The BBC Reith Lectures, 2002. Cambridge: Cambridge University Press; 2002.

Pugh K, Girod M. Science, art and experience: constructing a science pedagogy from Dewey's aesthetics. Journal of Science Teacher Education 2007:18(1);9–27.

Sartwell C. Six Names of Beauty. London: Routledge; 2004.

Scarry E. On Beauty and Being Just. London: Duckbacks; 2001.

Schechner R. Performance Studies: An introduction. London: Routledge; 2002.

Sutton C. Words, Science and Learning. Buckingham: Open University Press; 1992.

Winston J. Beauty, goodness and education: the Arts beyond utility. Journal of Moral Education 2006:35(3);285–300.