CREATIVITY IN THE SCIENCES

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In the light of government's Culture and Creativity Capital Plan, which details an intent to fortify investment in a range of cultural activities and enterprises, the Royal Irish Academy's Culture and Heritage Working Group has undertaken to generate position papers highlighting modes of creativity associated with public culture, public institutions and vernacular culture. Written by senior academics with strong ties to many of the state's cultural institutions, these papers constitute a set of reflections regarding the necessity for and social benefits of supporting enhanced attention to the creativity of Irish life.

IN THIS SERIES:

Royal Irish Academy Response to the Creative Ireland Programme
Mary Canning, MRIA.

Discussion Paper 1. Creativity in the Sciences
Luke Drury, MRIA.

Discussion Paper 2. 'The earth has music for those who listen': Creativity in Music in Ireland
Lorraine Byrne Bodley, MRIA.

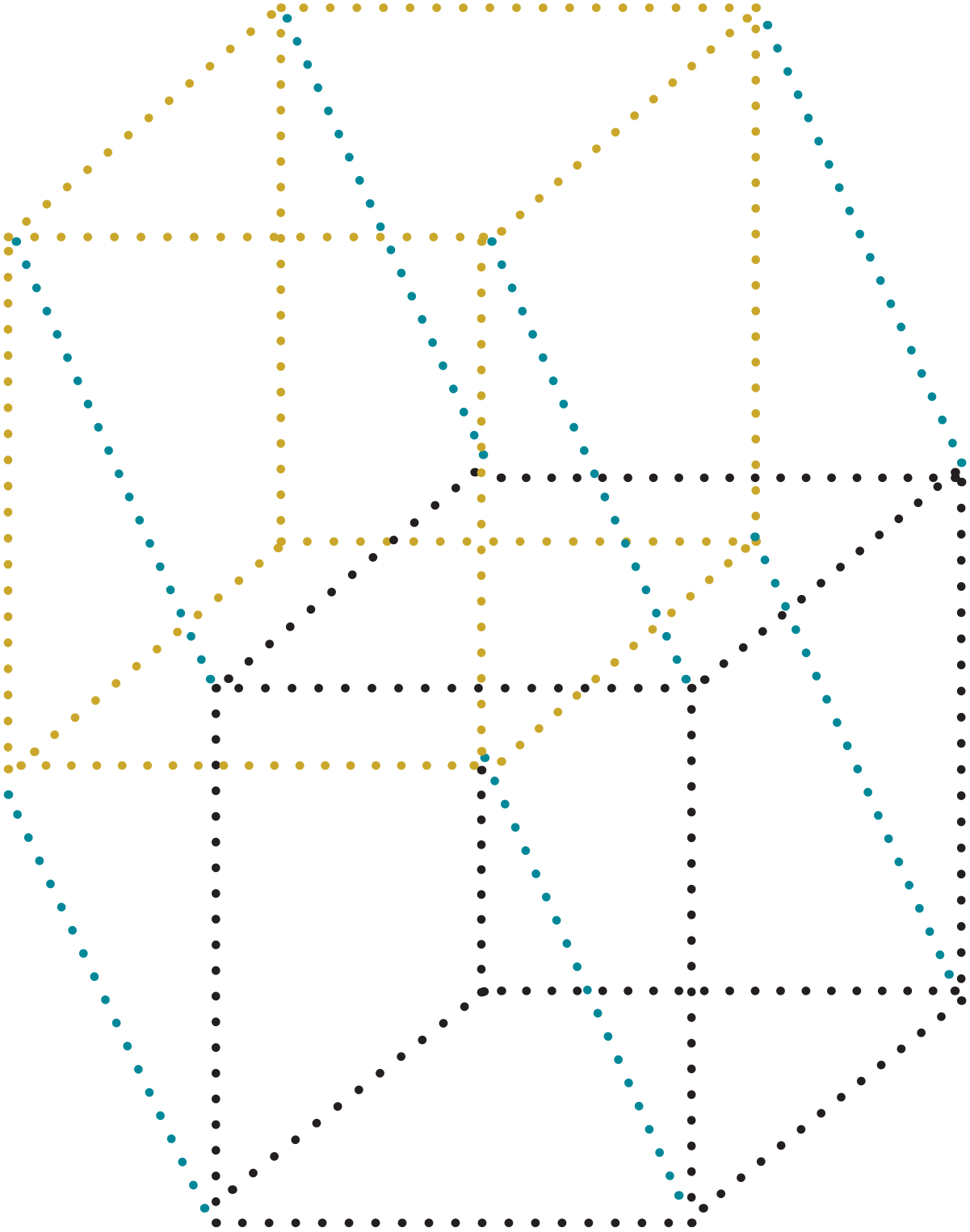
Discussion Paper 3. The Gaeltacht, the Irish Language, Folklore and Vernacular Creativity / An Ghaeltacht, an Ghaeilge, an Béaloideas agus Cruthaitheacht na nDaoine
Angela Bourke, MRIA with Diane Negra, MRIA.

Acadamh Ríoga na hÉireann
Royal Irish Academy

CREATIVITY is a function of being human: a common thread that can make sense of individual experience and communicate it, even in immensely complex forms, over great distances and many centuries. The Royal Irish Academy, Ireland's leading body of experts in the sciences, humanities and social sciences, has a long tradition of investigating, communicating, celebrating and supporting creative work in culture and the sciences on the island of Ireland, and representing it internationally. While recognising that creative expression can have significant economic importance, the Academy warmly welcomes the Creative Ireland initiative as an investment by the state in humane values, independent of commercial consideration.

Every culture finds ways of encoding hard-won wisdom, humour and expertise as resources for individuals and communities; every generation finds new ways to understand and use its heritage. Long famous for creative output in the form of books and film, Ireland has adapted quickly and flexibly to new forms of media culture, in rural as well as urban areas. Irish traditional music now has players and audiences across the globe, as the Irish language has speakers and learners. Meanwhile, research demonstrates that the Ireland of the past was much more receptive to in-migration, and to music and other cultural influences, than has been generally understood.

A major challenge in our globalised world is for encounters between cultures to be peaceful, respectful and mutually enriching. Diverse forms of national creativity deserve our fullest support. It should be noted, however, that creativity resists codification and commercialisation. The Royal Irish Academy, a hub of critical thinking, brings together expertise in many areas. It sees in Creative Ireland an opportunity to dig deep into that expertise, integrating the aims of celebrating Ireland's cultural heritage, honouring the cultural capital and creativity of in-migrants, and enhancing our country's international standing. The Academy offers these short papers on aspects of culture and heritage as discussion documents for Creative Ireland.



CREATIVITY IN THE SCIENCES

Creativity plays a crucial role in the sciences as well as in the arts. Indeed, the very idea of a 'Eureka moment' of creative inspiration has its origin in the well-known story of Archimedes's discovery of the law of buoyancy in hydrostatics while taking a bath. More recently August Kekulé's solution for the chemical structure of the benzene molecule, which came to him in a dream, and in an Irish context William Rowan Hamilton's discovery of quaternions at Broome bridge while walking into Dublin to chair a meeting of the Council of the Royal Irish Academy, are often cited as moments of creative inspiration in the natural sciences and mathematics. There is an extensive literature on this, a classic text being the work of the great French mathematician Henri Poincaré who meticulously documented his own intellectual processes in making a number of mathematical discoveries.[1] The case was well made by the great nineteenth century Irish physicist John Tyndall (discoverer of the greenhouse gas effect) in his address 'On the scientific use of the imagination', delivered to the British Association in 1870:[2]

[1] H. Poincare, 1908: *Science et méthode* (Flammarion, Paris).
[2] J. Tyndall, 1870: *The scientific use of the imagination* (Longmans Green and Co., London).

> But how are those hidden things to be revealed? Philosophers may be right in affirming that we cannot transcend experience: we can, at all events, carry it a long way from its origin. We can magnify, diminish, qualify, and combine experiences, so as to render them fit for purposes entirely new. In explaining sensible phenomena, we habitually form mental images of the ultra-sensible. There are Tories even in science who regard Imagination as a faculty to be feared and avoided rather than employed. They have observed its action in weak vessels, and are unduly impressed by its disasters. But they might with equal justice point to exploded boilers as an argument against the use of steam. With accurate experiment and observation to work upon, Imagination becomes the architect of physical theory. Newton's passage from a falling apple to a falling moon was an act of the prepared imagination, without which the 'laws of Kepler' could never have been traced to their foundations. Out of the facts of chemistry the constructive imagination of Dalton formed the atomic theory. Davy was richly endowed with the imaginative faculty, while with Faraday its exercise was incessant, preceding, accompanying and guiding all his experiments. His strength and fertility as a discoverer is to be referred in great part to the stimulus of his imagination. Scientific men fight shy of the word because of its ultra-scientific connotations; but the fact is that without the exercise of this power, our knowledge of nature would be a mere tabulation of co-existences and sequences.

Tyndall's 'imagination' is of course what we now call creativity and has been the subject of extensive research, mostly from a psychological perspective[3] although the neurosciences are beginning to enter the field as well[4]. This has shown, perhaps not surprisingly, that creativity is a very complex concept and not easy to pin down, although we all recognise it when we see it. As noted by Fink, *creativity is regarded as a performance or ability trait, preferably manifested in original, valuable, and socially accepted ideas, products, or works of art.*[5] It is not enough to have original ideas; they must be expressed in such a way that they are recognised as important by one's peers and they must have wide influence. Creativity thus combines concepts of novelty with significance and the ability to stimulate the production of related works. This clearly applies as much to the sciences as to the arts; the work of Einstein changed physics in much the same way that the expressionists changed painting. Afterwards there was simply no going back; the world had changed.

[3] M. Runco, 2004: 'Creativity', *Annual Review of Psychology* **55**, 657–87.
[4] E. Bowden *et al*., 2005:, 'New approaches to demystifying insight', *Trends in Cognitive Science* **9 (7)**, 322–8.
[5] A. Fink *et al*., 2007:, 'Creativity meets neuroscience: experimental tasks for the neuroscientific study of creative thinking', *Methods* **42**, 68–76.

Although we tend to emphasise the creativity of individuals, and their associated 'Eureka' moments because they make for memorable stories (such as Hamilton scratching his equation on the stonework of Broome bridge) much, if not most, creativity proceeds via a more gradual accumulation of ideas and their eventual synthesis, as exemplified by the great biologist Charles Darwin who spent over twenty years on information gathering, reading and reflecting, beginning in1837 with his first notebook entries, before the publication of his *On the origin of species* in 1859.[6] It would be a mistake to think that scientific creativity is only expressed in Kuhnian paradigm shifts;[7] more often it is a gradual process of transformation and refinement over an extended period. Nor is it confined to individuals. There is also a form of group creativity whereby a laboratory or research group produces consistently creative work, much as in the performing arts a theatre troupe or orchestra can consistently create more than the sum of its individuals. Of course, in many cases one can point to a group leader, or conductor or director, who has enabled and driven this creativity, but it is important to note that creativity can be expressed as much at the group level as in terms of special individuals. Indeed, in modern science, where large research teams are now the norm, this is probably the main form of creativity, with the exception perhaps of theoretical physics.

Another major defect of taking a historical approach and the popular obsession with stories of 'great men' and 'seminal moments of inspiration' is that it is grossly unfair to women. Indeed, even the phrase 'seminal moment' could be argued to betray a gendered use of language. There are plenty of examples of extreme creativity by female scientists, such as the astonishing achievements of Marie Curie, still the only scientist to win the Nobel prize for both chemistry and physics, or Emmy Noether, who did pioneering work in abstract algebra in addition to establishing a fundamental link between symmetries and conservation laws in physics; or more recently Jane Goodall, who has transformed primatology with her life-long study of chimpanzees. Of course in the past, and still today, there are cultural biases and social norms that discriminate against women. Regrettably these continue to colour our views, especially when we look through the lens of history, but at least we can be conscious of these biases and seek to counter them, as has been done, for example, in the excellent 'Women on Walls' initiative of the Royal Irish Academy and Accenture.[8] Indeed Blaise Smith's iconic painting as part of that initiative, of eight young female scientists, all ERC grant holders and working across the full range of natural sciences, is a powerful statement of female creativity in action that could well be picked up and used by Creative Ireland.

[6] E. Mayr, 1991: *One long argument: Charles Darwin and the genesis of modern evolutionary thought* (Harvard University Press, Cambridge, Mass.).
[7] T.S. Kuhn, 1962: *The structure of scientific revolutions* (University of Chicago Press, Illinois).
[8] Details of this project can be found at: https://www.ria.ie/public-engagement/women-walls (13 September 2018).

Finally, some thoughts on the 'two cultures' thesis introduced by C.P. Snow in his 1959 Rede lecture and subsequent book.[9] There is certainly an element of truth in Snow's analysis, but it is important to note that he was specifically commenting on the English educational and class system of his time and comparing it unfavourably with the German and (at that time) American systems. In many ways his criticism was that the English educational system, by emphasising a rather sterile knowledge of the classical humanities and disrespecting knowledge of the modern sciences, a tendency amplified by a class system underpinned by attendance at elite 'public' schools, was actually devaluing creativity and creating a false and dangerous dichotomy in British culture and society. Looking at recent events, with politicians quoting Latin and dismissing experts, it is hard to disagree. What he was not advocating was an intrinsic incompatibility between humanistic research and scientific research; quite the opposite in fact.

In summary, creativity is as much a feature of the sciences as of the arts; an innate expression of what it is to be human and curious about the world. It finds expression at both the group and individual level, in both men and women, in both young and old.

THE UNIVERSALITY OF CREATIVITY IS AN IMPORTANT THEME THAT SHOULD BE REFLECTED IN THE DISCUSSIONS AROUND THE CREATIVE IRELAND PROGRAMME AND SHOULD INFORM ITS POLICY RECOMMENDATIONS.

[9] C.P. Snow, 1959: *The two cultures* (Cambridge University Press, Cambridge, UK).

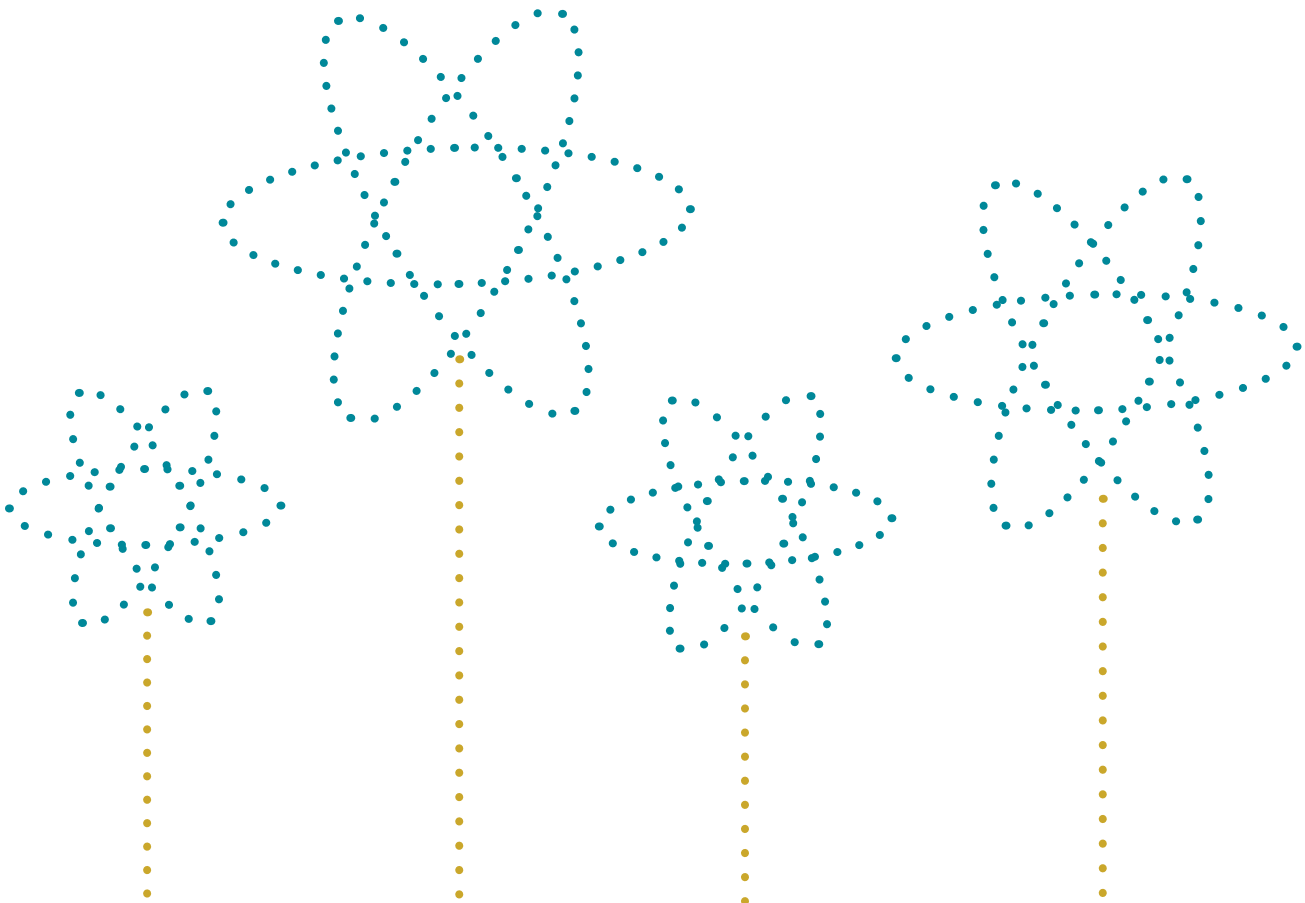
Educational implications

For both individual and group creativity there needs to be a nurturing, stimulating and receptive environment. Creativity is a delicate flower in need of careful cultivation. A lack of respect for divergent views, inappropriate norms, time pressures, overly frequent and formulaic evaluations; all of these inhibit creativity. Conversely, an environment that is open to new ideas, that values originality, and that accepts that occasionally people need time to think things through encourages creativity. This has important implications for science education. The whole modern movement towards 'enquiry-based learning' and away from rote learning of 'facts' is predicated on the idea that active learning, which engages the innate curiosity of individuals and teaches them the method of science, including its creative elements, is the most effective way to produce scientifically literate and engaged citizens.[10]

[10] See, for example, the French initiative 'La main à la pâte', available at: http://www.fondation-lamap.org (14 September 2018).

We need a society in which citizens understand how science works and are not just asked to believe blindly in science. Some will even go on to become 'citizen scientists' in their own right, but only if we allow creativity to be encouraged at all levels of the educational system. In a time when issues such as climate change, genetically modified organisms, vaccination, etc., are key topics of political debate we simply cannot afford to suppress creativity and curiosity in the teaching of science. To teach science badly is in some ways more damaging than not to teach it at all, and if we fail to convey to the next generation the excitement and creativity of science we are doing just that. But if we get it right, youth will respond positively as is demonstrated annually in the BT Young Scientist exhibition, which showcases the creativity that young Irish people are capable of when given the freedom to pursue their own scientific ideas.

MAKING CREATIVITY A CORE VALUE IN ALL AREAS OF OUR EDUCATION SYSTEM SHOULD BE A KEY AIM OF CREATIVE IRELAND.



Science policy implications

There are also important implications for research funding agencies. Any scientist will recognise that the creative spark is the elusive but vital element that makes the difference between great science and routine work. To have an idea that nobody has thought of before is the most intellectually satisfying thing that can happen to a scientist, and we are lucky if it happens a few times in our working lives. But to enable this creativity the mind must be prepared by a lot of preliminary work and given the freedom to explore unfashionable and superficially implausible concepts. All studies of creativity agree that there is an essential long initial period of incubation, when a problem is almost obsessively studied from multiple angles, and that the creative inspiration then bubbles up from the unconscious unexpectedly at a point when the conscious mind is engaged with some mundane task. It is a worrying aspect of our current obsession with the 'management', 'impact' and 'relevance' of scientific research that this essential freedom, first to obsessively focus on a problem with no obvious solution, and second to have the time to pursue esoteric and unfashionable ideas, is being lost, and with it the possibility of genuinely creative discovery. By its very nature,

creativity is unpredictable and often requires periods of reflection and apparently aimless investigation. Hamilton is known to have spent several years puzzling as to how to multiply 'triples' before realising that he needed to go into four dimensions,[11] and while he certainly had a vague idea of what he was trying to achieve it would never have been possible for him to write it down as a research programme with predetermined outputs, Gantt charts and risk mitigation strategies that could have been submitted as a standard grant application to a research funder. Yet his realisation of the quaternion algebra opened up totally new vistas in pure mathematics and is widely seen as the birth of modern abstract algebra. Our research policies need to recognise the importance of allowing some amount of curiosity-driven speculation even when there is no predictable outcome.[12] We need the freedom occasionally to dream and be creative or we will never achieve greatness in either the sciences or the arts.

Regrettably, science is often seen by policy makers and politicians merely as an enabler of technology, and technology in turn is regarded as an enabler of innovation and economic growth. But before science, before technology and before innovation comes the creative idea, the thought that nobody has had before, the insight than reveals new possibilities. Creativity feeds off creativity, and societies and political systems blossom or fade in as much as they enable human creativity in all its diverse aspects. Creativity in the natural sciences is an important part of this creative eco-system and needs to be fostered along with creativity in the arts. To be human is to be curious. We naturally have an instinct to solve problems and explore how the world works. We create models and representations of the world and we share them with our peers, both in the arts and in the sciences. These new ways of looking at the world certainly drive innovation, but that is not the primary reason we are inspired to acts of creativity.

A CREATIVE SOCIETY WILL BE AN INNOVATIVE SOCIETY WITH A FLOURISHING ECONOMY, BUT LOOKING FOR INNOVATION WITHOUT SUPPORTING CREATIVITY IS ULTIMATELY A FUTILE EXERCISE.

[11] T.L. Hankins, 1980: *Sir William Rowan Hamilton* (Johns Hopkins University Press, Baltimore, Maryland).
[12] This was one of the motivations of Éamon de Valera in his establishment of the Dublin Institute for Advanced Studies in 1940.

The need for a broadly based creative eco-system

Anthropology teaches us that all human societies exhibit creativity[13] and, to a greater or lesser extent, show respect for those individuals who have particular creative skills. We are lucky in Ireland that the ability to use language creatively is still held in high regard. Poets in Ireland still enjoy high esteem, something we should be proud of. Our scientists are less well known and our proud contributions to science are not valued as they should be in popular culture. One aim of Creative Ireland should be to redress this balance and generate a much broader appreciation of the value of creativity in science.

To a limited extent the move to replace the acronym STEM (Science, Technology, Engineering and Mathematics) with STEAM (Science, Technology, Engineering, Arts and Mathematics) goes in this direction,[14] as does the growing recognition that innovation

[13] E. Wilf, 2014: 'Semiotic dimensions of creativity', *Annual Review of Anthropology* 43, 397–412.
[14] Details are available at: http://stemtosteam.org (13 September 2018).

needs to be informed by art and design as much as by technology (Apple defeated Nokia in the mobile phone market not by better technology but by having a focus on design and aesthetics),[15] but this undervalues the importance of creativity in the sciences. Creativity is not the sole preserve of the creative arts, and the interactions go deeper than just adding design modules to STEM courses.

The evidence of history is that there are strong positive feed-back loops between different types of creativity so that even quite small societies can experience remarkable outpourings of creativity in many different areas simultaneously—one thinks, for example, of Periclean Athens, or renaissance Florence. With encouragement and support for an inclusive vision of creativity we may hope to replicate this experience in Ireland and make it one of the more culturally exciting places in the world to live and work, a magnet for talented individuals from all around the world, and a society that gives a meaning and purpose to life beyond simple economic gain.

SOCIETY IS MORE THAN THE ECONOMY; IDENTITY, MEANING, UNDERSTANDING AND BELONGING ARE AMONG THE KEY HUMAN NEEDS THAT CREATIVITY ADDRESSES, AND INNOVATION AND ECONOMIC PROGRESS ARE COLLATERAL, BUT WELCOME, BENEFITS.

[15] A point made by Professor Tuula Teeri, President of Aalto University, in her Leaders in Higher Education address to the Royal Irish Academy in November 2017.

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