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Manufacturing and higher education: A twin revolution

Piero Formica
Maynooth University, Ireland

With the start of the Industrial Revolution, manufacturing had its symbolic place in the factory, populated by a mass of workers and machines. Above it, the sky appeared starry – each star a new job, a new machine in operation. In short, the prospect was one of more jobs and more investment. But not only that. In Adam Smith's vision, set out in Book Three of *The Wealth of Nations* (Smith, 1776), manufacturing was the bearer of good governance, order, security and freedom, and so of the concomitant benefits for the lower classes. Thus economic development was able to proceed at a faster pace than in the past. In the firmament of the world economy, manufacturing is still a very bright star. Labour income is derived from various sectors including manufacturing: compared to the average, the contribution of manufacturing is about 20% higher. It deploys value creation geographically thanks to supply chains and the need for physical space and investment in tangible assets. The benefits brought by manufacturing are, therefore, a vital constituent in the lifeblood of the big five manufacturing exporters: the USA, China, Japan, Germany and Italy.

The Industrial Revolution was triggered by steam technology and later accelerated by electrification, which promoted the advancement of manufacturing. The intertwining of science, technology and the arts provided the energy that triggered the Knowledge Revolution. Knowledge in action is the energy source that ignites and drives the values of manufacturing in the controversial scenarios of the future of work. Estimates and opinions range from the optimism of the International Federation of Robotics (2017), according to which the adoption of robots in sectors such as the automotive industry will result in a net increase in employment, to the pessimism of the McKinsey Global Institute and IZA, a German think tank, which conclude, respectively, that 14% and 35% of jobs are vulnerable to automation (see Mahroum, 2021).

From specialists to polymaths

According to the first Chancellor of the University of California, Clark Kerr, the university is a 'multiversity' (Kerr, 1963). The term, which Clark coined in 1963, describes the multiple and parallel missions that universities have to fulfil. These missions range from education to moving forward the frontiers of knowledge (Bassett, 2020).

From their juvenile period onwards – for several centuries in other words – universities trained individuals by imparting to them knowledge that spanned a substantial range of subjects. Students acquired the *polymath* profile: that of a multifaceted and versatile individual who has learned many things and can excel in different bodies of knowledge and combine them to generate change.

For some time now, however, universities have been largely organized into disciplines isolated from each other and with few links between them. Each student enters a disciplinary silo, a well of knowledge of which they will plumb the depths. This is how one becomes a *specialist*, an individual who knows more and more about less and less. The deeper the well, the less the light penetrates it. Each specialization is a repository of knowledge, better known in professional circles as the 'knowledge map', where nothing should be left to chance and nothing improvised – a constraint that is perhaps reassuring but which at the same time exposes the outer edges to dramatic events. We need only recall the sinking of the RMS Titanic in 1912, of which it was said that nothing had been left to chance according to the knowledge of experts, who failed to recognize their errors.

In our present time, we run the risk of regressing towards mediocrity while a large set of converging technologies, such as cloud computing, machine learning, artificial intelligence, blockchain, brain–computer interfaces, nanotechnology, robotics, the Internet of Things, digital medicine, synthetic biology, genomics and genetic engineering, is rapidly gaining ground.

A revolution can present itself simultaneously as a season of light and darkness, an age of wisdom and madness, the best and worst time to live. To turn the tide in our favour, we need to hold hands to solve the real problem that, according to the behaviourial psychologist Burrhus

Corresponding author:
Piero Formica, Innovation Value Institute, Maynooth University, Maynooth, County, Kildare, Ireland.
Email: piero.formica@mu.ie

Frederic Skinner (1969), 'is not whether machines think but whether men do'.

It is up to human beings to think socially to communicate and collaborate so that robots are assigned tasks that benefit humanity. For this purpose, the university should shine the spotlight on the polymath. Informed by credible and consistent narratives of the role played by such versatile personalities as the French friar Marin Mersenne (friend and correspondent of René Descartes), students will be trained to participate in collaborative processes, building a bridge between science and humanities studies. Mersenne was a polymath who fought the custom of secrecy of the mathematical experts of his time – who were named *cossisti*, derived from the Italian word *cosa* ('thing') because they used symbols to represent unknown quantities. Known as 'le secrétaire de l'Europe savante' (the 'Secretary of Learned Europe'), Mersenne encouraged the exchange of ideas and working in a spirit of collaboration, thus pre-empting the birth of the Académie Française (Singh, 1997).

The rediscovery of the value of a multifaceted education that shapes the character of the polymath opens up entrepreneurial opportunities. Think of manufacturing in the health industry, where virtual reality requires artists and designers who can collaborate with scientists to develop new interactive and immersive models and tools for medical research, training and education, and drug discovery, simulation and modelling.

The interaction between academia and manufacturing

Universities search for new avenues for knowledge transfer to and interchange with manufacturing with a view to higher productivity, economic growth and entrepreneurial activity from the exploitation of scientific and technological knowledge. Transferring knowledge is more than a matter of communication that can be accomplished with information technology tools. The process is complex and nonlinear, with many interactions; it is not simply a question of knowledge linking academic researchers upstream and their business counterparts downstream.

Trustful and outward-looking knowledge brokers (the 'multilinguists' – intermediaries capable of understanding and practising in research and business cultures), with their excellent interpersonal skills, commercial awareness and contractual experience, can secure a better future for the flow of knowledge between universities and manufacturers. Trust is a critical component of the formula for those who would build bridges to meet the subtle and ambiguous challenges of transferring know-how, know-what, know-why, know-whom and know-when.

Universities must design and promote collaborative research to provide a context in which academic researchers can work alongside company employees to create, develop and test prototypes based on their reciprocal ideas. Collaborative research can be carried out in a 'collaboratory', an infrastructure linking teams of people from universities and companies with disparate cultures, different cognitive systems and skills. In a 'collaboratory', research is focused on specific company problems, and scientific research is carried out through interactions between academically trained corporate researchers and university researchers willing to apply their experimental results to practical use.

Academic enterprise

In innovation, what counts is the researchers' reflexivity and speed once they move from pure to applied research, from publication in authoritative international journals to the entrepreneurial translation of the scientific discovery. Academic enterprises demonstrate the ability of universities to master the entire knowledge chain: from creation to the dissemination, conversion and entrepreneurial exploitation of learning, scientific discoveries and technical breakthroughs.

By investing in academic enterprises, universities promote entrepreneurial innovation with new knowledge and participate in ventures to acquire companies whose products or services have high market potential that the entrepreneurs at their helm do not fully or adequately exploit. In medieval Bologna, the university triggered an intellectual movement that sowed the entrepreneurial seeds from which the modern liberal professions sprouted. As they did in those days, university communities should now strive for a change of phase, channelling their students and knowledge workers along the most promising paths of innovation that will lead to the creation of academic enterprises.

In the fields of food, medicine, health care, energy, the environment, construction techniques, clothing, furniture making and much more, the entrepreneurial imprint of scientific research is visible. Materials science, chemistry, biology and earth sciences are just a few categories in which new scientists are blazing trails for brilliant entrepreneurial insights. By moving towards entrepreneurship built on science, the number of intellectual capitalists in the entrepreneurial knowledge economy will grow among the university population.

Towards the future

The intellect cannot travel into the future with its back turned towards it and burdened with so much weight: that way, the goal of advancing knowledge will be lost. Experience counts up to a point. We perceive experience under normal circumstances in a normal environment and report our experience in everyday words, argued the philosopher

Paul Feyerabend (1975), quoting Aristotle. Extreme events push us out of normality.

The future of manufacturing lies in the interaction between two revolutions: the ongoing manufacturing revolution and the revolution of higher education, with the leadership of universities in transformation.

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