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Shaping the entrepreneurial university: Two experiments and a proposal for innovation in higher education

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Abstract

The paper delineates three elements of an entrepreneurial university in practice through innovations demonstrating the academic entrepreneurial transition: the *Novum Trivium*, Professors of Practice (PoPs) and Link initiatives. The *Novum Trivium* provides a model for the integration of entrepreneurship into a liberal arts curriculum, so that students learn how to put their knowledge to use and acquire a new language and new cultural understanding to interact globally. The PoPs initiative interlinks firm and university through shared dual roles in each setting, attracting back to the university on half-time basis scientific entrepreneurs from industry to serve as entrepreneurial role models. The Link projects build on ties between a leading entrepreneurial university (Stanford) and an aspiring one (Edinburgh), taking advantage of the fact that each university is already embedded in its region and could be linked to the other's entrepreneurial culture. The paper demonstrates how industry and higher education are integrated by these initiatives, with the elements of each embedded in the other through shared resources, people and practices.

Keywords

Entrepreneurial education, entrepreneurial university, entrepreneurial university linkages, *Novum Trivium*, Professors of Practice

Science and technology performance and outcomes are increasingly influenced by innovation-driven policies in which entrepreneurial universities play a key role (Audretsch et al., 2016). While national governments continue to be central players in these arrangements, especially with regard to budgetary, regulatory and legal elements, decreasing public budgets and fierce global competition for relevant knowledge flows in terms of both human capital and ideas require an urgent response from local, national and multinational public policy regimes. As a result, governments at various levels are turning more forcefully to the commercialization of research as a key driver of competitiveness and growth.

The means of delivering this "innovation in innovation" is not via the typical ivory tower, but through a vigorous pursuit of the third mission, the commercialization of knowledge, predicated on an entrepreneurial university transition that builds on the previous transition to the research university (Leydesdorff and Ivanova, 2016; Pique et al., 2018). A 12th-century organizational innovation dedicated to conserving ancient knowledge became the research university, focused on producing new knowledge in the 19th and early 20th centuries, and then the entrepreneurial university, with a remit for economic development, in the late 20th and early 21st century. The source and nature of this evolution arise from previous academic and

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industrial innovation in which knowledge played an ever-greater role. As we transition from industrial experience to knowledge as the central driver of productivity growth, the university as a source of knowledge must equally adapt to changing times.

The traditional ability of universities to create new types of ideas and academic roles needs to be matched by the capacity to equip students, faculty and the university itself with the necessary tools to interface with industry and the broader society (Ben-David and Collins, 1966). In the following, we set forth a set of three novel educational concepts to accelerate the transition to the entrepreneurial university: research-based Professors of Practice (PoPs), an initiative that integrates start-up firms with universities; the Link program, which integrates the entrepreneurial culture within academic institutions and their regions; and the *Novum Trivium*, a liberal-arts-based entrepreneurship training program. The authors have been involved, both as conceptualizers and implementers of various experiments and proposals for entrepreneurial academic innovation, and based this article on their experiences as well as on interviews with key actors.

The university for what?

The history of education is fraught with struggles about what the role of education is or should be in terms of labor market demands. The "first academic revolution" – the still ongoing transition from the teaching to the research university of the late 19th century – has been well documented (Cole, 2009; Jencks and Riesman, 1969). The "second academic revolution" (Etzkowitz, 1999) – the non-linear movement from the teaching and research university to entrepreneurial formats – is an emergent phenomenon of what is being charted even as it is being realized in various academic systems in the USA, Europe, Latin America and Asia (Benner and Sandstrom, 2000; Etzkowitz, 1983; Etzkowitz et al., 2008; Maculan and Mello, 2009; Mustar, 1998; Shane, 2004; Wong et al., 2007).

The university, with its steady flow-through of students with new ideas, is uniquely positioned to be the core institution of a knowledge-based society, but one needs to be reminded that the "cultivation of a market in academia was by no means a self-evident insertion" (Clark, 2006: 13). That is why, even in some versions of the entrepreneurial university, there is a limited view of the role of the university in society (Klofsten et al., 2019). For some observers, the entrepreneurial university format means the attainment of greater autonomy in academic systems that were formerly highly state-controlled (Clark, 1998). For others, the entrepreneurial university is equated to "academic capitalism," narrowly but increasingly focused on extracting commercial value from academic knowledge (Slaughter and Leslie, 1997). For still others, the entrepreneurial university plays a leadership role in a Triple Helix of university–industry–government relations to promote regional advancement and renewal (Etzkowitz and Klofsten, 2005).

The entrepreneurial university develops out of the ivory tower format, retaining its essential features even as it becomes part of a broader context for knowledge-based innovation. It is the latest phase in the working out of an "inner logic" of academic development that previously expanded the academic enterprise from a focus on teaching to include research. Most fundamentally, it involves faculty viewing their research and teaching activities in a new light, seeing how they can contribute to economic and social development as well as to the education of students and the advancement of knowledge. Such a university, infused with entrepreneurial attitudes and capable of taking initiatives at all levels, among faculty, students and administrators, takes a proactive stand in putting knowledge to use and in broadening the input into the creation of academic knowledge.

The progression is non-linear since entrepreneurship can also be generated from the teaching mission of the university, even in the absence of an entrepreneurial research tradition. Recognizing that European professors are at a greater distance from entrepreneurship in their normal academic working life than their US counterparts, European universities have, hitherto, focused on training students to develop start-up firms. Such start-ups have been based on research from an academic lab and thus involve the professor in an advisory capacity and as part-owner, but less often as the entrepreneur, taking direct steps to organize the firm. It is generally accepted that making entrepreneurs out of university scientists is not the best approach to creating spin-offs. It is expected that university researchers will wish to remain primarily academically committed and will prefer an ancillary advisory role in a firm, seeing themselves as potentially participating in the generation of a stream of firms from their research group.

However, PhD students who will be seeking full-time positions are increasingly aware that they will have to look beyond academia and are attracted by the adventure and independence that being a principal in a start-up can offer. Nevertheless, the traditional educational career path rarely provides them with the training and experience needed to organize a start-up or even to run a research group in academia. It is essential that they acquire business skills as part of their education. Just as graduates should be able to write an essay expressing their personal thoughts and a scientific paper placing evidence against hypotheses, so they should have the ability to write a business plan, setting forth an idea for a new project and a test of its viability.

The Professors of Practice concept

To achieve the entrepreneurial university, a series of organizational mechanisms and hybrid roles must be created in

partnership with various segments of society. Past initiatives have been relatively secluded from each other with clusters focusing on business development for instance, built with no input and formal linkages with centers for interdisciplinary academic research. Thus, in terms of entrepreneurship and innovation, there is a movement currently toward a synthesis in the form of clusters to enhance linkages with universities and provide a platform for firm formation. Consequently, the science park has evolved into a "science city," focused on translational research for socio-economic development (Etzkowitz, 2003). To further instantiate this integration, the Professor of Practice model, initially intended to focus on the mentorship of students in the US university system, has been extended in policy circles to incorporate dual roles as the norm rather than the exception. As a result, the appointment of a Professor of Practice is to be based on the revised idea that she or he is employed to do half-time inside the university (that is, work 50% of the time) and another half-time outside the university (that is, 50% in the start-up firm). The dual role function makes it possible for the Professor of Practice idea and concept to transition seamlessly from being a solely teaching option to include the research mission of the university.

The PoPs experiment was started in 2006 in the UK by Newcastle University and the One Northeast Regional Development Agency (RDA) at the suggestion of the Triple Helix Research Group (THRG) – a "science city" think-tank then located in the Newcastle University Business School (through the initiative of Professor John Goddard, the university's Deputy Vice Chancellor and a noted regional researcher with links to key regional actors through his former students). Whereas the classic Professor of Practice inducts an experienced professional into the university as a teacher to impart their experience to the next generation, the Newcastle PoPs model was built upon academic entrepreneurs.

The RDA matched university funds to start the project as a conjoint economic development/interdisciplinary project to create industry–university linkages. Within the academic side the lead actor was the Business School, which invited the medical and engineering schools as partners in the initial appointment of four PoPs (Dzisah and Etzkowitz, 2007). The novelty here is that the PoPs were expected to maintain their dual roles; that is, serving as role models for faculty and students on the one hand, while simultaneously maintaining their industrial connections. The success of this initiative has led to various projects, such as drawing together the university's drug discovery experts to undertake larger research projects and attract higher levels of funding, and a new doctoral program integrating business, engineering and medical disciplines to train future academic and industrial leaders in the medical devices field (NESTA, 2009).

As designed and conceptualized, a Professor of Practice integrates business and academic roles and collapses the university–industry divide, turning a conflict of interest into a confluence of interest. In principle, the model is built to integrate the internal and external roles in any of the three main missions of the university – teaching, research and entrepreneurship. Starting with dual roles in science and business, it is envisioned that the PoPs concept will spread across the university in variants appropriate to the Arts, Humanities and Social Sciences. Indeed, de facto, PoPs already exist in some fields – such as architecture, where it has not been unusual for a faculty member to be both a partner in an architectural firm and a university teacher.

As already noted, a Professor of Practice is envisioned as working half-time in academia and half-time in business, thus maintaining a career in each. It is expected that there will be flexibility in the precise proportion of time and the level of appointment. A Professor of Practice is initially appointed in a strategic research field that the university is developing, cross-cut by the various innovation fields that are crucial to developing its relations with industry (e.g., technology transfer and intellectual property rights, translational research and incubation, venture capital, entrepreneurship and innovation).

Similarly, the PoPs concept was designed to speed up the transition to the European entrepreneurial university. It is premised on a subset of high-tech entrepreneurs with strong academic credentials and research interests. These high-tech entrepreneurs have developed lines of innovative research within their firms, but the findings require further work that is more appropriate to an academic than to a firm setting. The prospect of a professorship, allowing them to build an academic research group and obtain grant funding, has the potential to be a pull factor for these scientific entrepreneurs to relocate some or all their firm's activities adjacent to the university. The research and the technology transfer capabilities of the university are thus both strengthened by this new professorial role (Dzisah and Etzkowitz, 2007).

The traditional Professor of Practice model was based on bringing distinguished practitioners from various fields in business, education and government into the university as teachers. For example, a venture capitalist was hired by the HAAS School of Management at the University of California–Berkeley, to organize an entrepreneurship program for MBA students. At Harvard's Kennedy School of Governance, the model is used to recruit PhDs who have had significant government careers to be teachers and mentors, while subject to less stringent publication requirements than traditional faculty.

The objective is a virtual circle of inflow and outflow among university, industry and government, with the Professors of Practice role institutionalized, not only in science, business and medicine as in the original Newcastle

experiment, but throughout the university. Soon after the PoPs project was organized, the leadership of the Communications Department visited the Triple Helix Research Group (THRG) to learn more about the model. It was suggested that, if recent hiring had been done on a PoPs basis, higher-level candidates could have been attracted to the department through the option to continue their professional role in a significant manner rather than having to make a full-time commitment to academia.

The PoPs model in its expanded form is applicable to the humanities. A PhD in Literature, for example, could be hired from the publishing industry to create a university press if one were lacking. The next step in developing the model is to extend it down the academic ladder by appointing postdoctoral fellows and lecturers as Researchers of Practice (RoPs), who will work half-time in an academic unit and half-time in the business development side of the university (e.g., in the technology transfer office, incubator facility or science park). RoPs will involve their students in analyzing the feasibility of technology transfer projects and in developing business plans with firms in the university's incubator facilities, along with traditional academic tasks.

Finally, "dual life" academic career structures may be institutionalized and made commonplace as a regular "line" in the university environment. Thus, the PoPs model could be extended to offer full-time faculty the opportunity to spin-out firms while retaining a significant academic role, long-term. After an initial leave period to allow time for the intense involvement of the early stages of firm-formation, the academic entrepreneur would return on a half-time basis, while continuing a lower level of involvement in the firm. Although there are, of course, individual exceptions, the full-time academic versus full-time entrepreneurship choice is typically either/or with a significant, but unknown, number of economic development opportunities foregone as a result of rigidified traditional academic career structures and organizational silos. In the medium term, the PoPs model could become self-sustaining as half-time positions are opened by virtue of entrepreneurial faculty taking time off to set up their ventures, allowing room for PhD entrepreneurs to be brought into academia from industry. A university faculty including a "critical mass" of 20% PoPs would, no doubt, be an entrepreneurial university in academic value and mindset.

The Link Model of Entrepreneurial Culture Transfer

The Link Model of Entrepreneurial Culture Transfer is built on the establishment of regional, national and international collaborations or "links" between universities in order to transfer entrepreneurial culture from one region to another. The model may include teaching collaboration, student exchange and faculty exchange. The "Link" is best exemplified by the Edinburgh–Stanford Link (ESL), which was a research, teaching and commercialization collaboration between the Universities of Stanford in California and Edinburgh in Scotland. It was born shortly after the MIT-Cambridge Institute, which "linked" the Massachusetts Institute of Technology in the US with Cambridge University in the UK. Whereas the MIT-Cambridge link established an MIT unit on campus to seek out relevant collaborations, the Edinburgh-Stanford link built on existing faculty relationships. To identify them, a call was made for proposals emanating from previous joint work and the most promising one was selected as the core of the Link project.

The ESL was focused on research collaboration between two departments of computer science at Stanford and Edinburgh, teaching collaboration between the Stanford Technology Ventures Program and the School of Informatics of the University of Edinburgh, and best practice learning between the Office of Technology Licensing at Stanford and Edinburgh Research and Innovation (the first formalized technology transfer office in the UK, established in 1969). In the ESL model, the aim was to transfer culture from Stanford University and Silicon Valley to the University of Edinburgh and Scotland. In particular, the ESL emphasized entrepreneurial education for informatics and digital design students who were enrolled in programs in the engineering and architectural schools. This is but one example of innovative developments to spur the growth of the entrepreneurial university. Future innovations will make the entrepreneurial transfer mechanism even more effective across regions, disciplines and countries.

Collaborative research funding

The largest portion of the ESL's budget, and ironically the least impactful, was its research funding. Approximately £6.0 million in total was allocated to 12 collaborative research projects over a span of 5 years (2002–2007). The projects were chosen by a committee of academics from both Stanford and Edinburgh. Unfortunately, the research projects were not market-driven and produced little intellectual property: to date, only one is in the proof of concept phase on its way to becoming a viable spin-out company. However, one positive but less measurable impact of this collaborative endeavor was knowledge and entrepreneurial culture exchange. Researchers from the University of Edinburgh were able to spend "time on the ground" in Silicon Valley and on the Stanford campus; likewise, academics from Stanford visited Edinburgh on an annual basis. Often, PhD or Master's-level students who were assisting the principal investigators on a research project would make the trip in their absence.

Commercialization and outreach

The next activity of the ESL was commercialization. Here the Link secured approximately £1 million from Scottish

Enterprise and £300,000 from the European Union through its European Regional Development Fund (ERDF) for a total of £1.3 million over a 5-year timespan (2003–2008). The ESL employed two business development executives (BDEs), one of whom was assigned specifically to the ERDF portion. It also employed a Software Architect, two Senior Software Developers and a Graphic Artist to help turn its research results into products. The initial goal was to develop prototypes that could be used for demonstrations in the marketplace to attract potential partners and buyers interested in furthering a relationship. The ESL's BDEs sought to license technology, spin-out new companies and solicit consulting projects for informatics researchers. Also, the team placed MSc and PhD students on research projects with Scottish-based technology companies.

Masterclasses

Each year the ESL ran a series of Masterclasses – short courses designed for and delivered to start-up companies from Scotland. Only executives were hand-picked and invited, and the courses were limited to 20 seats. They were taught by Silicon Valley entrepreneurs, venture capitalists and consultants. On average, 10 Masterclasses per year were put on the schedule. In 2007–2008 year, the team decided to hold 50% of the 12 courses scheduled in other Scottish cities, including Aberdeen, Dundee, Stirling, St Andrews and Glasgow, in order to reach a broader range of busy, innovative Scottish technology companies.

Entrepreneurship education and training

The third leg of the ESL was its technology entrepreneurship training program. The courses were "practical" and inspired by the Stanford Technology Ventures Program. They were "for-credit" and averaged approximately 50 students each, drawn from MSc and PhD students in the School of Informatics and School of Architecture, Culture and Environment (Digital Design and Media Program). The training program in "Informatics Entrepreneurship" I and II focused on ICT-oriented technology start-ups, while "The Digital Marketplace" focused specifically on Internet and media business start-ups. The highlight of the courses, besides visiting speakers from Silicon Valley, came in April of each year when student teams presented their business plans to a panel of "real" local business angels and venture capital investors who could and would actually make investments in the new ventures.

In addition to teaching these live courses, the ESL developed, for online e-learning, a series of six courses in technology entrepreneurship, along with another six in creative entrepreneurship. These initially served postgraduates and researchers at the University of Edinburgh, with the expectation that students from all Scottish universities might join later. The courses were positioned as optional, postgraduate skills courses, with certification to be sought subsequently.

Entrepreneur-in-Residence program

The ESL sponsored an Entrepreneur-in-Residence (EIR) program for graduating MScs who wanted to take the business plans and ideas they had developed in the "live" courses and explore them further. Building a prototype was an expected activity of the EIR. Each year the Link received about 10 applications for its EIR program (the EIR funding provided a nominal salary of £2,000 per month plus hardware, software and office space for 3 months). The EIRs were expected to move into the Edinburgh Pre-Incubator Scheme (EPIS) program or into the outside world. The EIR, however, admitted only 6 of 40 applicants, 4 of whom have gone on to continue building their technologies and businesses.

Networking and the Silicon Valley Speaker Series

Another function of the Link model is to play a part in growing the social and business networks around technology entrepreneurship. The Edinburgh Entrepreneurship Club hosted the Silicon Valley Speaker Series, which was followed by socializing and networking. In addition, the ESL attended and cooperated with a variety of organizations, including the Scottish Institute for Enterprise (SIE), Connect Scotland, Scotland IS, We-entrepreneurs, EPIS, The eLearning Alliance, The Entrepreneurial Exchange, GirlGeeks, The Creative Entrepreneurs Club, Scottish Developers, and others. The last official collaborative project for the ESL (Phase I) was the Stanford Roundtable on Entrepreneurship Education, themed around "Design and Entrepreneurship" – what design educators could learn from entrepreneurship educators and vice versa. A proposal for the ESL Phase II included a program to include three universities and to catalyze the formation of international technology ventures by students (Clouser, 2010; Papagiannidis et al., 2009).

The *Novum Trivium* concept of entrepreneurial education

As broadly conceived, the *Novum Trivium* model[1] provides a framework to train technically savvy and socially literate entrepreneurs. To this end, the proposal required a graduate to satisfy course requirements from liberal arts and language, technology, business management, entrepreneurship and innovation, and real-life internship practicum. The projection is that technical aspects of the existing curriculum for such programs as engineering will be enhanced by introducing students to business management and societal issues, as a preparation for both engineering and management roles.

The *Novum Trivium* is based on the premise that highly specialized degrees, appropriate to a relatively stable industrial society, are increasingly outmoded in societies undergoing rapid change. Degrees that were designed to meet specific needs of industrial society are often perpetuated, but the industries that required them have changed or may no longer even exist. Rather than a set of knowledge and skills to deal with a stable environment, a broader range of knowledge and skills is required to operate in societies in flux. The *Novum Trivium*, integrating the liberal arts with entrepreneurship, is the educational equivalent of the university's emerging entrepreneurial role in translating research into economic development, with both tasks dependent on the ability of the university to reconfigure itself to meet new needs, while retaining and enhancing classic strengths.

The *Novum Trivium* has a historical antecedent in the Tripos degree introduced by Cambridge University in the 19th century (Cambridge University, 2007). In medieval societies, a good university education included what were then known as the Seven Liberal Arts, parts of which were adopted from ancient Greece. These were divided into the *trivium* ("the three roads" in Latin) and the *quadrivium*. The *trivium*, as indicated by John of Salisbury[2] was concerned with "the power of language" and included the study of grammar, rhetoric and logic (dialectic). This study formed the basis of a Bachelor's degree, serving as a preparation for the *quadrivium*, the study of arithmetic, geometry, astronomy and music. These disciplines were concerned with the "secrets of nature" and led to a Master's degree, which served as background preparation for philosophy and theology – the doctoral prerequisites.

With the *Novum Trivium* the Cambridge model was reinvented as a degree program bringing together three diverse skill sets in an effort to make higher education appropriate to contemporary conditions, as opposed to three closely related specialties, the hallmark of the Tripos model (Cambridge University, 2007; Etzkowitz et al., 2012). The *Novum Trivium* built on the traditional disciplinary education, but the addition of entrepreneurship and innovation were meant to translate knowledge into use. There was also a requirement that a student be immersed in knowledge of a language and culture other than her or his own. In short, the *Novum Trivium* model for higher education reform was intended to generate technically literate business people, entrepreneurial scientists and engineers with a global orientation and a boundary-spanning cross-cultural awareness. This educational reform involved the restructuring of the relationship between the university and society, the internal transformation of the university into a more interdisciplinary mode and the reorganizing of the link between secondary and tertiary education.

The fundamental drive at the core of any educational system is the ability to train free enquiry minds and to educate the future leaders of social institutions to thrive in a competitive, dynamic and knowledge-based environment. The *Novum Trivium*, as a generic innovative degree program, attempted to bridge the Science–Arts divide. It was designed to produce graduates with a sound understanding in three areas:

(i) disciplinary education in the traditional set of academic disciplines – Biglan's taxonomy of academic disciplines: hard/soft or pure/applied (Biglan, 1973);
(ii) entrepreneurship and innovation studies related to local and global contexts; and
(iii) languages and cultural studies of countries other than one's own.

The aim of bridging science and business cultures was to address the development requirements of regions, in addition to offering new and emerging hybrid disciplines with future multidisciplinary faculty, since existing undergraduate programs were slow in adapting to the changing structure of societies. The concept also addressed the need for culturally aware students capable of working in a global labor market.

The *Novum Trivium* model for higher education reform as a result blended the traditional disciplinary education of the academic curriculum with contemporary disciplines such as entrepreneurship and innovation – not as separate entities existing within an institution but integrated across all subject specializations. This approach gave graduates the opportunities to be efficient participants in the real-world setting and encouraged them to engage in firm formation as individuals and collective entrepreneurs and to be active global citizens as well. The advantages of a broad-based education are evident in the educational backgrounds and later success of the co-founders of Apple Computer. Steve Wozniak, a University of California–Berkeley engineer, was profoundly influenced by literature, including Henry David Thoreau's *Walden*. Steve Jobs received a humanities-oriented education at Reed College, including a course in calligraphy that influenced the firm's concern with typography and design. These individualistic experiences are encompassed in the *Novium Trivium* degree program to provide technical and humanistic literate entrepreneurs.

In our view, public discontent with the pre-existing educational structure is based on the tendency to view education reforms solely in terms of access to higher education. This misnomer gives credence to the perpetuation of the erroneous impression that an expansion of higher education systems alone can provide an efficient panacea for social and labor-market problems (Wotherspoon, 1995). This policy incongruity provided an avenue for designing a broader and more flexible educational model geared toward equipping students with the ability to adjust to rapidly changing real-life situations. In this regard, the *Novum Trivium*

proposal for higher education reform was a call for an effective blending of theoretical and practical knowledge through the engagement of stakeholders within and outside the university. The *Novum Trivium* model is globally oriented through internship opportunities, and language and cultural training in a country different from that of the host university. This interactive "sandwich" degree incorporated a learning process within and outside the university that should prepare students for the knowledge economy. The *Novum Trivium* is, on the one hand, a far more structured model than the US major/minor electives scheme and, on the other hand, broader than the typical European degree program focused on a single subject. The degree program attempted to integrate the best of both worlds into an education that would equip students with a blend of various science disciplines, entrepreneurship and innovation and that was also grounded in cross-cultural literacy.

In addition, the *Novum Trivium* provided an incremental process with built-in review and adjustment mechanisms that allowed its unique features to be gradually disseminated across various educational systems. In an era of global networks based on the penetrating forces of information and communication technologies, language and culture have become more than communication tools. They are industries of their own, and there are huge benefits to be derived from an international education that incorporates technical components, vocational, language and cultural skills in students. Language and cultural studies are important in any type of degree. An adequate grounding in the arts and social sciences provides an initial training for personal and future developments.

In its nascent stage, the three core elements of the *Novum Trivium* were not necessarily designed to be equal in size but proportionately embedded so as to offer an academically credible route with progression. Languages were to be offered ab initio as some applicants may not always have taken high/secondary school modern language courses, and there ought also to be some cross-cultural awareness. International students whose first language was not English, for example, were to study English and British culture. Students were to spend one semester abroad, undertaking an internship in a science industry, as well as studying the language and culture of the country they visited. This experience was to inform their dissertation, which acted as a capstone of the program, pulling all the various elements together.

The *Novum Trivium* was envisaged to start in phases, with the initial phase focusing on just one or two languages and partners abroad, and then becoming fully-fledged as time and resources were generated. In the long run, this was to enable students learn the usefulness and importance of public–private and civil societal partnerships for innovation and development. In addition, it was to invariably advance science–society interactions, as these international work-related learning processes break boundaries and transform cultures. In fact, a well-integrated *Novum Trivium* was adaptable in scope and partnership across the globe and in different academic fields. The added value for the proposed disciplines and professions was that it compared favorably with existing courses and programs in the same field at various universities at national and international levels.

Conclusion: Innovation in higher education

In an increasingly knowledge-based society, the requirement for linking industry and higher education demands not an ivory tower but rather an entrepreneurial university with a broader mission for innovation than the research university, which was invented in industrial society. To meet this demand, governments, academic scientists and industrial managers have, over the last few decades, responded with varying knowledge capitalization and research funding initiatives (Drucker, 1995; Etzkowitz, 2002; Nonaka and Takeuchi, 1995). These policy intiatives are themselves a response to the shift from labor-intensive growth to knowledge-based innovation. As a result, there is now a growing intimacy among university, industry and government, in structure and content, as well as a closer relationship between science and technology.

This, for critical observers, is not surprising because in a knowledge-based global economy, a flow of commercializable knowledge is the ultimate condition for long-term success (Crawley et al., 2020). In fact, the emergence of polyvalent research fields with simultaneous theoretical, technological and commercial potential have long provided a conduit for the growth of science-based clusters (Etzkowitz and Viale, 2010). The recognition that knowledge is infused with both practical and theoretical attributes has provided a fodder for the involvement and adoption of various roles in firm formation by some academics, and the involvement of industrial researchers in academic pursuits. Since univalent knowledge follows a sequence from basic to applied research typically carried out in different time periods, at different sites and by different people, the emergence of polyvalent knowledge therefore enables the breaking of disciplinary boundaries, making multidisciplinarity and de-differentiation more prominent (Delanty, 2002; Gibbons et al., 1994). Interdisciplinary research organizations (IDOs) consequently become more central to future academic development than disciplinary departments, with the research group rather than the individual researcher the key academic actor (Liu et al., 2020). In parallel, educational programs and the boundaries between university and society may expect to be redesigned. As the ivory tower is transmogrified into an entrepreneurial behemoth through the rethinking of its core educational modalities, in parallel with virtual and augmented reality technologies, which are substituting for some of the in-person collegiality that has been hampered by the

Covid-19 restrictions, the dawn of a new university format is heralded.

A university education should include training in various disciplines as well as specialization, with a few key topics being universal. As Cardinal Newman, the 19th century proponent of liberal education put it, "If the various branches of knowledge, which are the matter of teaching in a university, hang together, none can be neglected without prejudice to the perfection of the rest" (Newman, 1959: 102). However, what is essential in one era may be peripheral in another, which argues for a continual revision process to guard against academic ossification, the natural result of disciplinary turf protection. De facto, Stanford students have made elements of computer science a component of most undergraduate degrees by double-majoring in computer science and another academic specialty. Combining employability and a universal methodology with personal interests is the outcome of an informal bottom-up innovation process.

The wisdom of an academic combinatorial logic, linking the liberal and the technical, was earlier perceived at MIT and became the basis for the transformation of a "trade school" into a university with high technological and humanistic standing (Keyser, 2011). For example, in the early 20th century, MIT feared that if its students were trained only in narrow technical disciplines, they would end up working for people with a broader education: Harvard graduates would become managers and MIT graduates their employees. Thus, MIT built strong humanities departments, especially in fields relevant to technological issues, on the premise that it was necessary for its graduates to have a broad liberal education in order to become effective leaders.

The concept of the entrepreneurial university has expanded the horizon of the MIT insight in order to build a bridge between the "two cultures" gap (Snow, 1959) from the other side as well; that is, humanities graduates with little knowledge of science. That divide produced the overly specialized degrees that have been in place in most universities for centuries. The "two cultures" bifurcation emanated from the narrow UK degree programs, which lack the US general education element which requires a minimum acquaintance with the arts and sciences, and/or a selection of courses from a minimum of five to a maximum of 10 categories. The traditional argument was that the US university-level general education was a remedial make-up for the higher-quality training of the European gymnasium at the secondary level, allowing early specialization while guaranteeing that breadth was achieved. This was perhaps true when higher education was confined to relatively small elites who had passed through such schools. In a global knowledge-based social order, however, it is less likely, especially given the "massification of higher education" (Gibbons et al., 1994) and the role of global knowledge networks in productivity growth and socio-economic development.

A "tectonic shift" in the relationship between science and the economy has offered the opportunity to create new technologies and industries. It is also the basis for the emergence of interface professions and new entrepreneurial opportunities. This requires the renovation of university degree programs formulated in a previous era of industrial specialization. Modest change may be accommodated within existing organizational formats. Under novel conditions new organizations and roles are created. At the institutional level, there need to be changes in the rules of the game for relations among societal institutions and the creation of a revised industry–higher education relationship.

In the late 19th century, growing science-based electrical and chemical industries initiated relations with universities to serve their research needs and to supply them with personnel. These labor market oriented advances were conducted across well-defined borders between the academic and commercial domains. The university's increasing involvement in science, however, engendered a more organized approach to managing research and its practical consequences. For instance, when researchers at the University of Toronto invented an insulin treatment for diabetes in 1922 the university found that it had to patent and license the technology in order to protect itself from potentially unethical manufacturers (Bliss, 2007). As the university takes on an entrepreneurial role, industry takes on some of the values of the university, sharing as well as protecting knowledge, giving rise to the "open innovation" framework.

In the early 21st century, a new set of internal reforms, beyond the interface mechanisms implanted in the late 20th century, represents the next stage of the entrepreneurial academic transition. The *Novum Trivium* provides a model for the integration of entrepreneurship into a liberal arts curriculum, research-based Professors of Practice interlink firm and university through shared dual roles in each setting, while the Link projects create reciprocal ties between leading and aspiring entrepreneurial universities, sharing resources and experiences. The entrepreneurial university model creates a framework in which the university is embedded in its region and linked to other regions. Through these three initiatives, industry and higher education are integrated as overlapping institutional spheres, with the elements of each embedded in the other through shared resources, people and practices with the ultimate outcome being the shaping of the entrepreneurial university and overall innovation in higher education.

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Notes

1. This section draws on the paper by Etzkowitz et al. (2012), in which a detailed curriculum design is provided.
2. The trivium reference is made in *Metalogicon*, one of John of Salisbury's most important works, published *c*1159, next to the *Policraticus, sive de nugis curialium et de vestigiis philosophorum.* Both works constitute valuable sources on the nature of medieval scholastic education.

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