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From Spheres Towards Spaces in Design and Creative Technology

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Abstract:
Knowledge and creativity have always played a key role in the economy and New Zealand is rapidly moving towards a knowledge-based strategy for growth. Increasing prominence has been given to the role of New Zealand's universities in stimulating economic growth through industry related research, technology commercialisation, high-tech spin-offs, and nurturing entrepreneurial mindsets. Universities are notoriously difficult to change; however the society and culture in which they operate are adapting and accommodate change at a faster pace. Universities in New Zealand have made efforts to see social, government and corporate relationships evolve, however, there are still issues to be addressed and difficulties to be overcome with respect to orthodox disciplines and procedures that need to evolve within the university to facilitate the transition.

This paper draws on existing literature related to tri-lateral networks and hybrid organisations to inform the development of a new initiative focused on developing a research system that cuts across both organisational and disciplinary boundaries. The new initiative brings together business, government, researchers, students, and the wider community from the South Auckland region. The initiative is intentionally adaptive, fluid and transient in order to accommodate multiple models of co-evolution of knowledge. The paper sheds new light on the evolving role of university and outlines a future direction for the initiative and a range of measures that can be used to evaluate its successes by presented the initial stages of a longitudinal case study of an emerging initiative. It frames a computational agent-based simulation where alternative architectures can be benchmarked in their capacity to promote entrepreneurial activity.

Keywords: Mode 1, Mode 2, Mode 3, Knowledge Production, Triple Helix Model, Innovation and Entrepreneurship, University Industry Partnership.

1. Introduction

The role of modern universities is changing in the knowledge based economy, and as a result, the relevant models of organisation can be expected to change (Carayannis & Campbell, 2014). New Zealand, like other countries, is moving toward a knowledge-based economy. Universities are charting a course for this transition to an innovation-driven economy, emphasising the strategic role of intellectual capital and its commercialisation to create value and jobs. Increasing prominence has been given to developing university frameworks that lead to a more open environment in innovation and entrepreneurial activities, i.e., "entrepreneurial universities".

This paper aims to elaborate how developing such environments may be achieved and explains the transition among Triple Helix configurations by introducing the concept of 'Spheres to Spaces'. In this model, a space is considered to be fluid and transient conceptual unit with its own lifecycle that exists within an organisational structure. Such spaces create an adaptive knowledge-based innovation system. With this new 'Sphere and Spaces' approach it is believed that universities can support entrepreneurial leadership to enable higher engagement with business and community. The study is of relevant interest to show how the mission based community and local government may need to be reformed toward entrepreneurial models to enable growth.

The 'Spheres to Spaces' model is currently being deployed as a pilot initiative focused primarily on the creative industries and community in order to bring together business, government, researchers, students, and the wider community from the South Auckland region. The paper begins with a review of literature related to the role of Universities and different models of knowledge production. This is followed by an elaboration of the 'Spheres to Spaces' model and the early stages of a case study of its implementation in Design and Creative Technology. Progress to date and measures of success are discussed, including the framing of a computational agent-based modelling approach to study these models. The paper concludes with an outline of the limitations of the approach and avenues for future deployment.

2. Role of Universities

The fundamental purpose of many modern Universities has not changed significantly over the last centuries in terms of the provision of teaching and the conduct of research. In recent years there has been a growing focus on different operational models for Universities. For example, there is evidence that the traditional paradigm of scientific discovery, dubbed 'Mode 1' by Gibbons et al. (1994), is being superseded by a new paradigm of knowledge production. Mode 1 knowledge production is characterised by the hegemony of theoretical or experimental science; by an internally-driven taxonomy of disciplines; and by the autonomy of scientists and their host institutions. In contrast, 'Mode 2' knowledge production is socially distributed, application-oriented, transdisciplinary, and subject to multiple accountabilities (Harloe & Perry, 2004; Nowotny, Scott, & Gibbons, 2003).

Under the traditional paradigm of 'Mode 1' there are clear tensions between the roles of the university in servicing the needs of local economies and civil societies, those of the national state and the more abstract concerns of learning and the pursuit of knowledge (Delanty, 2001; Scott, 1990). Indeed, some authors go as far as to suggest that the normal state of affairs for much of the 20th century would be a significant degree of separation and segregation between the university, the state and the market (Harloe & Perry, 2004). Such separation is diminished by the emergence of 'Mode 2' production of knowledge. Gibbons et al. (1994) describe five features that characterise this model of knowledge production as shown in Table 1.

Table 1: Features of Mode 2 Knowledge Production (Adapted from Thorpe and Holt (2007))

Feature	***Description***
Knowledge produced in the context of application	Real world problems and theoretical development are co-negotiated
Transdisciplinarity	Research draws together a diverse range of disciplinary perspectives in response to the problem at hand
Heterogenity and organisational diversity	Research involving a transient team of researchers, drawn together from different organisational settings
Social accountability and reflexifity	Processes of research involve reflection on the real time production and consumption of knowledge, and the wider societal impacts of that knowledge
Diverse range of quality controls	Where the quality of the knowledge is judged in more than purely academic terms. Peer reviewed academic journals are one form of quality control, whether the research is usable, actionable and appropriate opens up a far wider set of debates

MacLean, MacIntosh, and Grant (2002) identify a gap in the literature in terms of empirical accounts specifically related to the detailed features of Mode 2 and go on to suggest that different combinations of these features may be present in different instances of Mode 2 knowledge production. However, in general Mode 2 knowledge production "perceives the weakening or collapse of the modern university, the disappearance of scientific disciplines and the atrophy of peer control over the direction and content of research programmes" (Shinn, 2002, p. 600).

In conjunction with this shift to Mode 2 knowledge production, the Triple Helix (Etzkowitz & Leydesdorff, 1995) stance has emerged, which states that a university can play an enhanced role in innovation in increasingly knowledge-based societies. In contrast to Mode 2 knowledge production, the Triple Helix maintains historical continuities and structures. Existing relations between industry, government and the university persist, but to these models of action and learning is now added a supplementary layer of 'knowledge development', a layer in which specific groups inside academia, enterprise and the government collaborate in order to address emerging problems in a complex and changing economic, institutional and intellectual world.

Carayannis and Campbell (2009) suggest that the Mode 1 and Mode 2 knowledge production are not mutually exclusive, and indeed that the Triple Helix model of knowledge can be incorporated alongside these with innovation systems and knowledge clusters to produce Mode 3 knowledge production. They also suggest that the Triple Helix can be expanded to the Quadruple Helix that places the media-based and culture-based public alongside industry and business. Carayannis and Campbell (2009, p. 206) go on to suggest that "an advanced

knowledge system may integrate different knowledge modes" and therefore "a co-evolution, co-development and co-specialisation of different knowledge modes emerge".

It is arguable whether the use of the term Quadruple Helix adds any clarity to the understanding of such a system of knowledge production. For the purpose of this paper, the use of the Triple Helix label is maintained but the classification of Industry is broadened to any form of enterprise, whether it is business, social, cultural or community based. However, the authors agree with Carayannis and Campbell (2009) that an modern, entrepreneurial university should be able to embrace multiple modes of knowledge production in an agenda of co-evolution, co-development and co-specialisation.

Many Universities are extending their teaching and research capabilities from educating individuals to shaping organisations in entrepreneurial education and incubation programmes, and provide new teaching and research formats exemplified by inter-disciplinary centres and hybrid organisations such as science parks, academic spin-offs, incubators and venture capital firms (Etzkowitz & Ranga, 2010). A recent survey of the top global and Asian engineering schools shows an increased awareness of creative and innovative dimensions (Sosa & Wang, 2014) that are in many ways a prerequisite for such ventures. However, such ventures in this vein tend not to exhibit some of the fundamental features associated with Mode 2 knowledge production, particularly the transient nature of the endeavour. This remainder of this paper presents the early stages of design for a Mode 3 based knowledge production system that will in future produce empirical data regarding its performance and acceptability to address the gap in such data identified by MacLean et al. (2002). The following section outlines the development of the initiative from its grounding in the Triple Helix model.

3. Model of Sphere to Spaces in Design and Creative Technologies

The previous section outlined at a high level various different models of knowledge production outlined in the literature. This section first describes in more detail the Triple Helix model, with the caveat that "Industry" is considered instead to be "Enterprise" that includes a much broader scope of possible interaction. This leads into a description of the "Spheres to Spaces" model.

3.1 Knowledge Space

The Triple Helix model (Leydesdorff & Etzkowitz, 1998) is a model through which reflects the changes in the knowledge based economy and the new transformation in the modern university. A triple helix relationship between university, industry and government means the evolution of institutional relations. The Triple Helix model justifies a new configuration of the institutional forces within innovation systems with opening up of companies traditional closed to exogenous forces. As knowledge has become an ever more important and crucial part of innovation, the university, as an institution for the generation and dissemination of new scientific and technological knowledge has a more important role in generating innovation in the form of facilitating human transfer and as an incubator of new ventures.

According to Etzkowitz and Ranga (2010), the evolutionary process in the Triple Helix system involves transition from the 'statist' stage in which government controls academia and industry, to the laissez-faire state relationship between the three institutional spheres; and finally to the hybrid stage in which each institutional sphere keeps its own distinctive characteristics and at the same time also assumes the role of the others. The evolutionary process underlying the Triple Helix system is graphically depicted in Figure 1 below. It is at the hybrid stage of the Triple Helix network development that the dynamics of innovation are expected to be fully at work in creative technology education (Abdrazak & Saad, 2007). In other words, each helix would be connected to another thus assisting in the formation of interfaces between them. Industry will gain some of the values of the university, sharing as well as protecting knowledge; research groups in industry would collaborate with public and university research groups to achieve common long-term strategic goals (Etzkowitz & Leydesdorf, 2000).

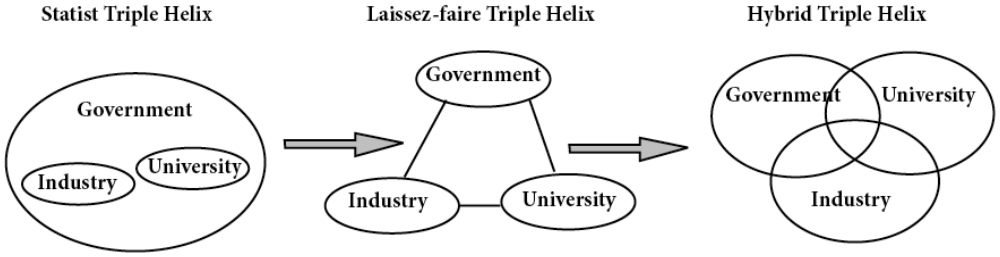


Figure 1: Hybrid Triple Helix Model (Abdrazak & Saad, 2007)

The hybrid triple helix framework has been applied in the Faculty of Design and Creative Technologies (DCT) at Auckland University of Technology (AUT) in order to create a strong environment to generate new spaces and encourage entrepreneurship in various technological fields depicted in Figure 2. In this model the definition of "Industry" has been broadened to that of "Enterprise", whether it is economic, social, cultural or community-based. In the hybrid model, universities are expected to acquire some business skills to effectively carry out activities, such as commercialising their research and setting up their own start-ups. The "Sphere and Spaces" in DCT builds on university values but de-emphasises the labelling of departments and disciplines and thus shifts the role of academia in the educational sector.

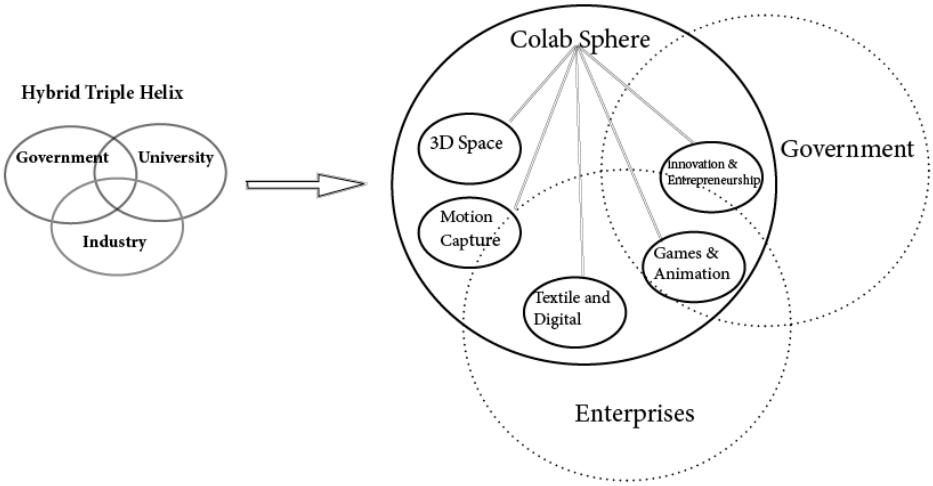


Figure 2: Sphere to Spaces Model of DCT

The "Sphere to Spaces" framework was created to build interaction between enterprise, government and the university to create a strong environment to generate new initiatives and encourage entrepreneurship. The framework is being piloted in Colab, the collaboratory for Design and Creative Technologies at the Auckland University of Technology. In its current form, Colab was created by the merging of two previous academic units. These were the Interdisciplinary Unit (IU), which existed primarily as a teaching unit, and an externally funded research project also (somewhat confusingly) called Colab. The new unit, referred to as "Colab 2.0", is considered an experimental sandbox that can deploy teaching and research strategies that are outside of normal organisational comfort zones and has made considerable progress in teaching innovations (Connor, Karmokar, & Whittington, 2015; Connor, Marks, & Walker, 2015). The emerging focus of the unit is to build on such teaching innovations and explore new models of research and research partnership.

In the current pilot, Colab is being redefined as a collaborative space for academics and students to work together with business and community agencies to foster innovation and solve complex problems emerging from the new economy. Colab is a "Sphere" with collection of internal spaces that are conceptual units that have their own life cycles. In line with the features expected of Mode 3 knowledge production, some spaces are intended to be purely project based and exist for the duration required to resolve a particular problem that is co-evolved with other partners. In contrast, other spaces may exist with in traditional structures associated

with Mode 1. Any list of spaces will always be incomplete and inaccurate at any time other than that of writing as the environment adapts and changes. At present, spaces within the Colab sphere cover the broad spectrum of technology and entrepreneurship. These include play, interaction and games; motion capture; virtual and augmented reality; innovation and entrepreneurship; textiles and wearable computing; and additive manufacturing. In a sense, these spaces are domain specific but allow interactions among domains and specific synergies among functions and projects. This allows free flow of information and transfer of knowledge between enterprise, university and government and disestablishing the discipline model of university. The Colab Sphere acts a connector between various internal and external stakeholders.

The 'Sphere and Space' framework is intended to act as a catalyst to innovation. In chemistry, a catalyst speeds up chemical reactions by reducing inhibiting factors to bring the necessary participants in the reaction together without actually being consumed in the reaction. Because catalysts are not consumed, they are recycled and reused in multiple reactions. In the same way, the new model for Colab has the potential to speed up social and economic innovation by providing a unique environment to bring together the right people with the right skills to lead this change in a sustainable manner. The Colab Sphere exists within the university structure, but each space is intended to challenge the common perceptions of the organisation hierarchy and promote new patterns of research and learning by cutting across both organisational and discipline boundaries. The Colab community includes academics, industry partners, collaborators, postgraduate and undergraduate students, working in research, education, knowledge sharing and development of creative technologies and transdisciplinary practices.

One of the foci of Colab Sphere in this emerging economy is the creation and commercialisation of knowledge protected by intellectual property (patented high-tech innovations and trademarked designs, proprietary specialised knowledge assets and processes, and copyrighted creative contents).

3.2 Adaptive Spaces

The formation of spaces across domains provides new opportunities to learn and experiment in adaptive environments. It encourages potential for new ideas and entrepreneurial activity. Students and academic staff inhabit a place with transdisciplinary capabilities and formally transfer technological knowledge across departments rather than relying solely on informal ties. Colab students draw on recognised AUT strengths in areas like creative technologies, design thinking, entrepreneurship, ICT, and business.

In the 'Sphere and Spaces' framework students may also be trained and encouraged to become entrepreneurs (Connor, Karmokar, & Walker, 2014) and inspired to take up new roles as firm founders in a society that has become overly dependent on a small set of large corporations, some of which are "dinosaurs" that are becoming extinct, while others have moved significant parts of their enterprise abroad. It provides an opportunity to explore what's new in the evolving digital economy. It supports emerging entrepreneurs, startups, companies, organisations and others operating in the creative technologies sector. The Colab Sphere support students, researchers and external partners to co-develop ideas into tangible, customised products, experiences and services.

Colab was tasked with the mission of significantly expanding the teaching of cross-disciplinary courses to students in engineering, design, computing and business. Colab is also involved in raising awareness and interest in various spaces among students, staff and industry partners, which is performed through outreach activities such as meet ups, skunks works, workshops, symposiums, bringing prominent entrepreneurs and venture professions to campus.

4. Discussion

The reconceptualisation of Colab as a living lab to act as a catalyst for innovation is currently in the initial deployment phase. A number of issues and challenges have been identified and measures of success have been defined. At this stage, no comparisons between the 'Spheres and Spaces' and other triple-helix implementations is made, however this will be addressed in future work. Instead, this paper outlines a computational agent-based simulation model which will allow alternative architectures to be benchmarked in their capacity to promote entrepreneurial activity which can be conducted alongside real world data collection.

4.1 Issues and Challenges

The development of the 'Sphere and Spaces' model based on triple helix framework encourages knowledge transfer across disciplines and different schools of AUT but it has its own challenges and issues. Several authors have attempted to highlight the complexity of collaborative relationships in the context of an education environment. Several challenges arise from both internal and external entities, including different timeframes between universities and industry; academic research focuses on long-term challenges and moves more slowly whereas business R&D is time-sensitive. The cultural divide between universities and industry include a different stance to intellectual property (IP). Of additional concern are one-dimensional, transactional and fragmented approaches between the parties, often without an understanding of each other's value proposition. Additionally, the value generated by engagements may be distributed across the organisation, not just the point of interaction. Industry feedback on workforce readiness of graduates has highlighted a lack of soft-skills in many graduates. Contractual issues may hinder or delay engagements between universities and industry. A comparative scarcity of large enterprises investing significantly in R&D in New Zealand leads to a lack of large business investments in higher education R&D. Due to the bureaucratic structure of universities there is lower demand and ability of private enterprises to commercialise university knowledge.

The traditional academic career path may seem to discourage applied research with industry. Interdisciplinary programmes have suffered from Equivalent Full Time Students (EFTS) based funding models, leading to competition, rather than collaboration, between departments. The 'Sphere and Spaces' framework is more knowledge based, and competing for EFTS based funding is a requirement that erodes the real objective Colab. This is a result of a more rigid bureaucratic control by the government-funding model. There is lack of understanding and relationship between spaces for the creation of transdisciplinary innovation and knowledge transfer. One of the key challenges is therefore enabling Colab to function as an independent unit that is free from the need to "own" a set of undergraduate and postgraduate programmes to provide EFTS-based income.

A key part of this shift is the development of entrepreneurial mindsets and capabilities toward knowledge transfer and commercialisation. In particular, this calls for a fundamental re-examination of the traditional university. Universities need to undergo key changes in their organisational structure and incentives system in order to change the mindset of their staff towards building knowledge based spaces

4.2 Measures of Success

One of the features associated with Mode 2 and Mode 3 models of knowledge production is the use of diverse range of quality controls (Gibbons et al., 1994; Thorpe & Holt, 2007). Similarly, the evolution of Colab as model of co-location and co-creation also requires a range of indicators of success. These are currently under development but a number of measures have already been identified as initial indicators.

4.2.1 Increased Rate of Research Outputs

Whilst the publication of research outputs such as journal articles would be considered a traditional measure of success, it still remains a valid and necessary measure for any academic venture. It is expected that rate of publication for Colab will significantly increase due to the creation of new research opportunities.

4.2.2 Publication Diversity

Beyond the number of publications produced, a more useful measure for a unit focused on transdisciplinarity and collaboration will be diversity. This can be broken down into a number of factors, for example diversity of authorship where research outputs are co-authored between transient teams within Colab as well as authors from government and enterprise. A corollary of the Triple Helix model is that all parties will embrace the value systems of each other, so it should be expected that external partners will contribute to the production of research outputs. Another element of publication diversity will be a shift away from traditional disciplinary foci, an example may be computer scientist and engineers being involved in the production of exhibitions as opposed to the more usual conference and journal papers.

4.2.3 Enterprise Sponsored Postgraduate Study

As Colab, the government and enterprise come together in mutual understanding and appreciation of each other's value systems there should be an increase in the number of sponsored postgraduate students working on applied research projects that benefit all.

4.2.4 Increased Number of Collaborative Projects

As with the above measure, there should be an increase in the number of collaborative projects undertaken by Colab staff in conjunction with external partners, as well as activities of co-location and co-creation with undergraduate and postgraduate students.

4.2.5 Diverse Nature of Collaborative Projects

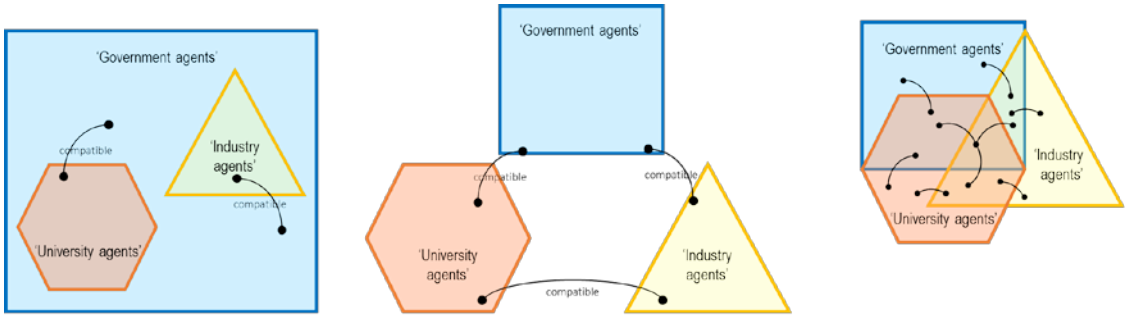
As well an increase in the number of collaborative projects, it is expected that the nature of such projects will also change. Of particular note will be the evolution of projects that draw together a wide range of different disciplines on timely and appropriate projects. Somewhat counter-intuitively, another element of measure this success will be the number of projects that don't produce formal research outputs. This will reflect that Colab has embraced the value systems of government and enterprise.

4.3 Computational simulations of Sphere to Spaces

In this section a computational approach is specified based on classic agent-based simulations of collaboration (Axelrod, 1997) where agents exchange information under a range of experimental conditions and the output is used as an 'intuition pump' (Dennett, 2013) to support reasoning about the factors and conditions at play in the 'Sphere to Spaces' model. The output of the planned simulation will be used to inform and refine the evolving design of the Colab Sphere and also be compared to real world data when collected.

In an otherwise ergodic or fully convergent cellular automata, Axelrod introduced a number of stylized mechanisms to model issues linked to conflict resolution and culture dissemination across populations of diverse actors. One specific observation derived from that modelling work is the emergent formation of closed clusters from incorporating an interaction rule in the system: the condition that agents only interact with neighbouring agents with whom they have at least one element in common. These "stable regions of shared culture" give shape to "cultural zones" within which agent interaction is mediated by compatibility of their evolving values (Axelrod, 1997).

The resulting static structure used here as a baseline model is the "Statist Triple Helix" depicted in Figure 3a, for example where 'Government agents' are compatible with 'Industry agents' and with 'University agents', but these two are incompatible between each other. In extensions to these models, Sosa and Gero (2005) studied agent mobility in these systems, capturing patterns of innovation from transfer of values between stable regions. In this vein, agent displacement between zones represent the linkages in the "Laissez-faire Triple Helix" model depicted in Figure 3b. Such 'exploration' behaviour enables agents to travel between stable regions and trigger local changes modifying the shared values (or status quo) in a group. Lastly, a model of a "Hybrid Triple Helix" model as depicted in Figure 3c can be implemented by growing 'porous barriers' between dynamic zones constantly evolving from the influx of new values and new members (Epstein, 2007), thereby representing Spaces connecting Spheres in our model. The measures of success described above can be operationalised into this computational simulation framework, in order to benchmark their capacity to promote entrepreneurial activity.



a) Segregated stable regions "Statist Triple Helix"

b) Links between stable regions "Laissez-faire Triple Helix"

a) Dynamic overlap between regions "Hybrid Triple Helix"

Figure 3: Computational simulation models of the Triple Helix model

5. Conclusion

This paper has described the early development of a new initiative that is intended to create a strong environment to generate new spaces and encourage entrepreneurship in various technological fields. The

design of the initiative draws on understandings of Mode 2 knowledge production and the Triple Helix model to ensure an adaptive sphere of spaces that embraces transience and transdisciplinary capabilities in order to act as a catalyst to innovation by bringing together staff, students and external organisations. The evolving design of the initiative is being informed by the development of an agent based simulation model that can be used to estimate how different approaches may produce differing performance against defined measures of success. Future work will focus on finalising both the measures of success and the simulation model to produce empirical data that can be used to benchmark actual data collected during the operational life of the initiative.

References

Abdrazak, A., & Saad, M. (2007). The role of universities in the evolution of the triple helix culture of innovation network: The case of malaysia. *International Journal of Technology Managment and Sustainable Development, 6*(3), 211-225.

Axelrod, R. (1997). *The complexity of cooperation: Agent-based models of competition and collaboration* P. S. i. Complexity (Ed.)

Carayannis, E. G., & Campbell, D. F. (2009). 'Mode 3' and 'quadruple helix': Toward a 21st century fractal innovation ecosystem. *International Journal of Technology Management, 46*(3), 201-234.

Carayannis, E. G., & Campbell, D. F. (2014). Developed democracies versus emerging autocracies: Arts, democracy, and innovation in quadruple helix innovation systems. *Journal of Innovation and Entrepreneurship, 3*(12), 1-15.

Connor, A. M., Karmokar, S., & Walker, C. (2014). *Doing entrepreneurship: Towards an entrepreneurial method for design and creative technologies*. Paper presented at the DesignEd Asia Conference 2014, Hong Kong.

Connor, A. M., Karmokar, S., & Whittington, C. (2015). From stem to steam: Strategies for enhancing engineering & technology education *Internation Journal of Engineering Pedagogies, 5*(2), 37-47.

Connor, A. M., Marks, S., & Walker, C. (2015). Creating creative technologists: Playing with(in) education. In N. B. Zagalo, P. (Ed.), *Creativity in the digital age* (pp. 35-56). Berlin: Springer.

Delanty, G. (2001). *Challenging knowledge: The university in the knowledge society*. Buckingham: Oxford University Press.

Dennett, D. C. (2013). *Intuition pumps and other tools for thinking*. New York, NY: WW Norton & Company.

Epstein, J. M. (2007). *Generative social science: Studies in agent-based computational modeling*. Princeton, NJ.

Etzkowitz, H., & Leydesdorf, L. (2000). The dynamics of innovation: From national systems and 'mode 2' to a triple helix of university - industry- government relations. *Research Policy, 29*(2), 109-123.

Etzkowitz, H., & Leydesdorff, L. (1995). The triple helix--university-industry-government relations: A laboratory for knowledge based economic development. *Easst Review, 14*(1), 14-19.

Etzkowitz, H., & Ranga, M. (2010). *A triple helix system for knowledge-based regional development: From "spheres" to "spaces"*. Paper presented at the Triple Helix 8 International Conference Madrid.

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., & Trow, M. (1994). *The new production of knowledge: The dynamics of science and research in contemporary societies*. Thousand Oaks, CA: Sage.

Harloe, M., & Perry, B. (2004). Universities, localities and regional development: The emergence of the 'mode 2'university? *International Journal of Urban and Regional Research, 28*(1), 212-223.

Leydesdorff, L., & Etzkowitz, H. (1998). The triple helix as a model for innovation studies. *Science and public policy, 25*(3), 195-203.

MacLean, D., MacIntosh, R., & Grant, S. (2002). Mode 2 management research. *British Journal of Management, 13*(3), 189-207.

Nowotny, H., Scott, P., & Gibbons, M. (2003). 'Mode 2' revisited: The new production of knowledge. *Minerva, 41*(3), 179-194.

Scott, P. (1990). *Knowledge and nation*: Edinburgh: Edinburgh University Press.

Shinn, T. (2002). The triple helix and new production of knowledge prepackaged thinking on science and technology. *Social studies of science, 32*(4), 599-614.

Sosa, R., & Gero, J. S. (2005). A computational study of creativity in design: The role of society. *AIEDAM, 19*(4), 229-244.

Sosa, R., & Wang, P. K. (2014). Creativity awareness in engineering schools in asia. *International Conference on Advanced Design Research and Education*, 140-143.

Thorpe, R., & Holt, R. (2007). *The sage dictionary of qualitative management research*. Thousand Oaks, CA: Sage.