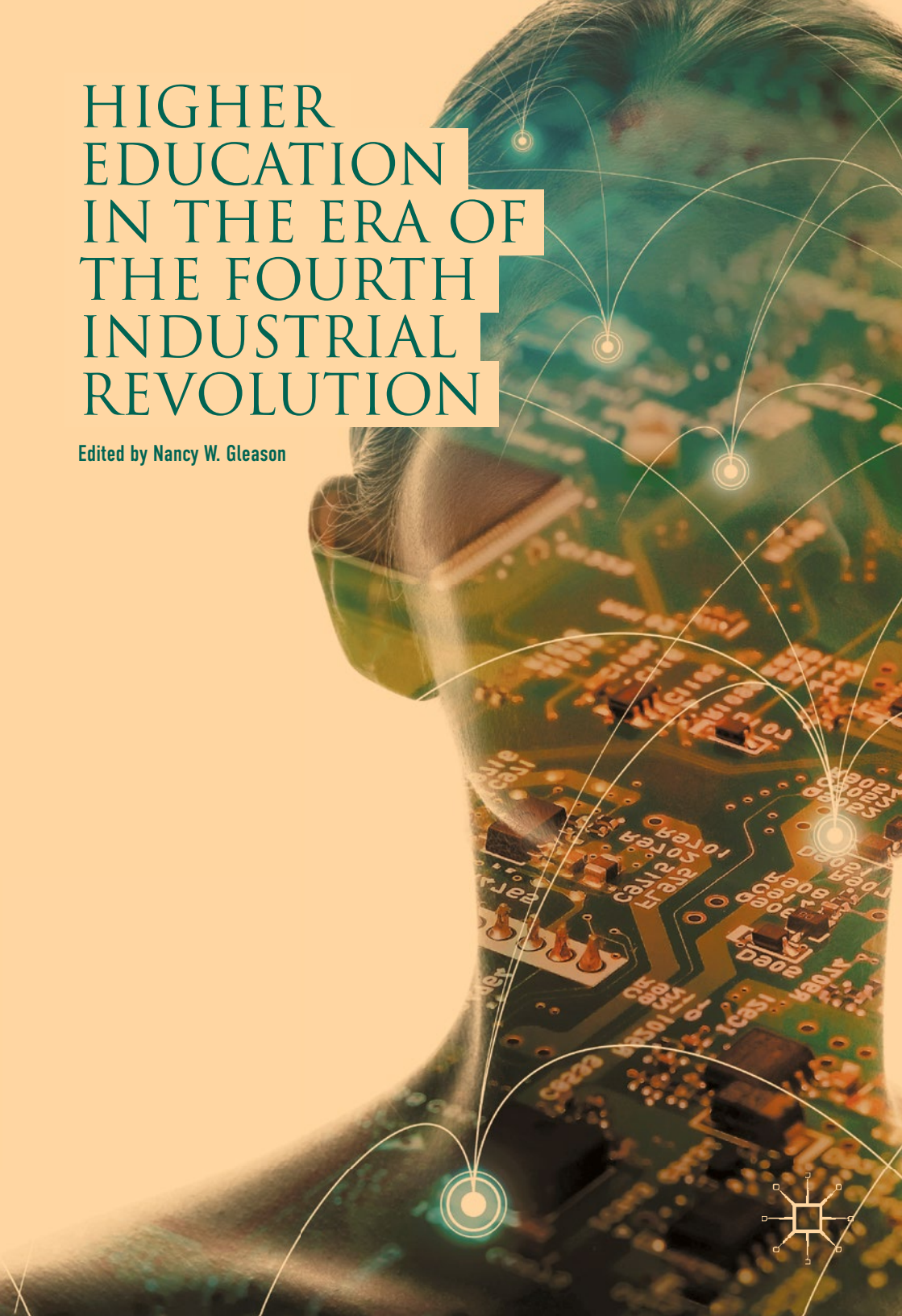
HIGHER EDUCATION IN THE ERA OF THE FOURTH INDUSTRIAL REVOLUTION

Edited by Nancy W. Gleason



Higher Education in the Era of the Fourth Industrial Revolution

Nancy W. Gleason
Editor

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For Alexander, Theodore, George, and Isabelle
And to my parents, Mary Clark Webster and William Harvey Webster, III
Thank you!

Foreword

It is exciting to live in a time of real change and transformation. It is also scary.

Higher education is in the throes of massive change and transformation along with the rest of society. Higher education is more accessible, to more people, in more places, and in more ways than ever in human history. And, maybe, for that very reason, the *what*, the *how*, and even the *why* of higher education are under question. These are exciting times. And, scary.

This book is an important contribution to understanding one very important dimension of the inevitable transformation of higher education: automation. It uses the lens of the 'fourth industrial revolution' to look at what is happening within the world of higher education and why. It is ambitious in its scope and yet grounded in its focus on actual examples from around the world. It looks at the great trends in higher education, but does so by focusing on case studies and examples from around the world. It is optimistic in its tone, but not shy of looking at potential winners and losers.

Most importantly, it is intrinsically global in its outlook. This global outlook, in itself, is a significant contribution. A conundrum of our field is that even as all higher education, everywhere, has become manifestly global, the operation, management, and strategy of higher education have remained staunchly parochial. This book sheds the parochialness and, for that reason alone, is worth reading.

This is not a book of predictions about the future of higher education as much as it is a guide to navigating the many, and mostly unknown,

transformations that are inevitable in higher education. It raises the questions we need to ask as we navigate the transformations. And in highlighting experiences from around the world, it points us in the direction of good practice. The importance of interdisciplinarity is emphasized throughout, as learners of all ages must meet the challenges of the automation economy with creativity and curiosity. In this global community we can all learn from each other and the case studies in this book offer important examples of how some around the world are working in the classroom and at the policy level to adjust the learning environment in preparation for the future.

The contexts of the fourth industrial revolution and of automation are important anchors for this discussion. Automation is a tangible reality for anyone in higher education. It is an area where the change, as well as the options, is palpable and real. The case studies in this book look at the question of automation for myriad perspectives, but all are grounded in the realizable policy and action. In bringing it together, the book makes a real contribution not only to our understanding of what is happening but also to the practical steps that readers could take in shaping the transformations that are bound to take place.

I am particularly delighted to read this volume because it exemplifies the intellectual energies and inherent optimism of Dr. Nancy Gleason, who has been working to improve student learning for more than 15 years. I first saw this energy and optimism in action when she was a student in my classes at the Fletcher School of Law and Diplomacy at Tufts University in 2005. I saw it again some years later when we worked together in the Netherlands at the International Programme on the Management of Sustainability (IPMS), sponsored by the Sustainable Challenge Foundation. I am delighted to see the same enterprise and optimism reflected in this volume.

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I am appreciative to all the contributors to this volume for their ideas and commitment to impactful higher education. They are each preparing minds for life and work in the fourth industrial revolution in unique ways and with tireless energy. Measuring learning is difficult, each of the authors in this book offers some baseline context for higher education in the era of the fourth industrial revolution. I am also grateful to Professor Adil Najam for contributing the Foreword to this volume. His passion for higher education around the world, understanding of complexity as it relates to, both climate change and higher education, as well as unique administrative experience make him ideal to introduce the importance of the book. I thank him for his time and thoughts.

I am also grateful to my editor, Sara Crowley-Vigneau, Senior Editor, Humanities and Social Sciences, China & Asia Pacific at Palgrave Macmillan Press. I thank all of my Yale-NUS College students for keeping me to task—the hard work of challenging them just enough to nurture new ideas is rewarding because of who they are, who they are becoming. I especially thank Calvin Jing Xun Yeo for his time working on the book with me. His formatting diligence and focus have made this a stronger book. Finally, I thank Lily Seah for her support throughout the preparation of the manuscript.

I acknowledge and thank the Dean of Faculty's Office at Yale-NUS College and the Dean of Educational Resources & Technology Office at Yale-NUS College for enabling this volume to be published on Open Access.

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Contents

1 Introduction 1
Nancy W. Gleason

Part I Higher Education Themes in the 4IR Context 13

2 Globalizing the Liberal Arts: Twenty-First-Century Education 15
Pericles Lewis

3 Educational Mobility and Transnationalization 39
Peidong Yang and Yi'En Cheng

4 Academic Library Futures in a Diversified University System 65
Lorcan Dempsey and Constance Malpas

Part II How Education Has Begun to Adapt: Case Study Assessment 91

5 Innovation Education in China: Preparing Attitudes, Approaches, and Intellectual Environments for Life in the Automation Economy 93
Rosaline May Lee and Yanyue (Selena) Yuan

6 Regenerative Development in Higher Education: Costa Rica's Perspective 121
Eduard Müller

7 Singapore's Higher Education Systems in the Era of the Fourth Industrial Revolution: Preparing Lifelong Learners 145
Nancy W. Gleason

8 Adopt Fast, Adapt Quick: Adaptive Approaches in the South African Context 171
Bo Xing, Lufuno Marwala, and Tshilidzi Marwala

9 The Fourth Industrial Revolution and Higher Education 207
Bryan Edward Penprase

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List of Figures

Fig. 4.1	Examples of online information resources	71
Fig. 4.2	Comparison of institutional profiles between the AAU and Oberlin Group	81
Fig. 4.3	Variance in institutional purpose within the Oberlin Group	82
Fig. 5.1	Towel wringing gadget	115
Fig. 5.2	Towel wringing gadget drawing	116
Fig. 5.3	Operation of towel wringing gadget	116
Fig. 5.4	Example of detachable tableware	117
Fig. 8.1	New production resources: data	172
Fig. 8.2	4IR: Dissolving human and machine boundary	175
Fig. 8.3	Deep mining paradigm	192
Fig. 8.4	The structure of UJ's new engineering and built environment qualifications	194
Fig. 8.5	The UJ's mining discipline: enrolment overview	195
Fig. 8.6	The UJ's mining discipline: access and excellence overview	197
Fig. 8.7	The UJ's mining discipline: inclusiveness snapshot	198

List of Tables

Table 4.1	Changing functions of the library	76
Table 4.2	Differing directions of a services-oriented library	86
Table 5.1	List of items to choose from for the desert island challenge	114
Table 7.1	Singapore's growing higher education sector	157

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CHAPTER 1

Introduction

Nancy W. Gleason

Introduction

In a July 2017 piece in *Inside Higher Ed*, Joshua Kim asked: "Why is it that books about technological-induced economic change tend to focus on every other information industry except for higher education?"[1] The answer is because no one knows quite what is happening yet. It is too new. The automation economy, resulting from the technologies of the fourth industrial revolution (4IR), is changing the way we live and work. Information transfer is no longer the sole purview of institutions of higher education (HE). Information is everywhere and the collection of big data means we have brand new kinds of information. Several good books have already been released on what needs to change in HE, but they lack a detailed perspective on how some elements of HE—liberal arts, youth themselves, and libraries—are already changing, as well as what nations are doing to adapt their HE institutions. HE is changing around the world

[1] Joshua Kim, "'The Fourth Industrial Revolution' and the Future of Higher Ed," *Inside Higher Ed*, July 10, 2017, https://www.insidehighered.com/blogs/technology-and-learning/fourth-industrial-revolution-and-future-higher-ed.

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already as a result of the fast-shifting global economy and the types of employees and thinkers it demands. This book offers a first glimpse at new global trends in HE, and how nations around the world are responding in their national HE systems in order to provide readers insights into how that is already happening on the ground and what is likely to come next. HE will have to change, quickly, in collaboration with governments and industry to respond to the automation of knowledge and production.

The Fourth Industrial Revolution

What is the phenomenon we are now experiencing? The first industrial revolution emerged in the 1780s with steam power, making humans more productive. Then in the 1870s the second industrial revolution emerged with the development of mass production and electrical energy. The third industrial revolution emerged with the development of IT and electronics, which enabled more efficient production. We are now in a new phase where the fusion of several technologies is not only automating production, but also knowledge. There are many working to classify and name the phenomenon we are all experiencing. Talk of "Industry 4.0" emerged from Germany's manufacturing industry in the early 2000s. The changes that are occurring are happening now because humans have finally developed the computing capacity to store massive amounts of data, which in turn can enable machine learning. The outcome of this is the development of what are called cyber-physical systems (CPSs). The term cyber-physical systems was coined by the US National Science Foundation in 2006 with the hosting of several workshops on artificial intelligence and robotics and the declaration that CPS would henceforth be a major area of research. Ragunathan Rajkumar et al. provide a useful explanation of what these complex systems are and their broader implications:

> Cyber-physical systems (CPS) are physical and engineered systems whose operations are monitored, coordinated, controlled and integrated by a computing and communication core. Just as the internet transformed how humans interact with one another, cyber-physical systems will transform how we interact with the physical world around us. Many grand challenges await in the economically vital domains of transportation, health-care, manufacturing, agriculture, energy, defense, aerospace and buildings. The design, construction and verification of cyber-physical systems pose a

multitude of technical challenges that must be addressed by a cross-disciplinary community of researchers and educators.[2]

Erik Brynjolfsson and Andrew McAfee of MIT outlined what they call the dawn of the *Second Machine Age* (2MA), which classifies a shift to the automation of knowledge. Their argument follows that the first machine age was about the automation of manual labor and physical strength. In the 2MA, the technological progress in digital hardware, software, and networks is about the automation of knowledge. This is underpinned by:

1. "exponential growth of Moore's law yielding a new regime of computing;
2. the digitization of everything; and
3. the emergence of an infinite number of combinatorial possibilities for innovation between the two."[3]

In 2016, economist and Executive Chairman of the World Economic Forum (WEF) Klaus Schwab published a book and launched WEF efforts in the area of what he called the 4IR.[4] Klaus Schwab's WEF 2016 theme, which coincided with his book, *The Fourth Industrial Revolution* officially sounded the alarm that labor costs were about to be disrupted and the way we live and work would be permanently altered by the introduction of CPSs. The world was put on notice that increased economic growth will no longer correspond with increased job growth and discretionary spending.

This volume has adopted the phrase 4IR to describe the phenomenon we are all experiencing because it aptly applies to both the technology shifts of 2MA and how people will live with it. Indeed, we are in the 2MA, but that age represents revolutionary changes to everything. The transition is profound and the pace unprecedented as we learn to harness the massive amounts of data being collected. Like earlier industrial revolutions, the impacts will emerge for years to come. Many nations are now preparing for the shifts coming, and HE is a key player. In 2018, CPS and full artificial intelligence are still, for the most part, in development form,

[2] Rajkumar, Insup Lee, Lui Sha, and John Stankovic, "Cyber-Physical Systems: The Next Computing Revolution," in *Proceedings of the 47th Design Automation Conference* (New York: ACM, 2010), 731.

[3] Brynjolfsson and McAfee, *The Second Machine Age* (New York: W. W. Norton, 2014).

[4] Schwab, *The Fourth Industrial Revolution* (New York: Crown Publishing Group, 2017).

but with significant importance to transportation, manufacturing, health care, energy, and agriculture, they are likely to change our lives over the next ten years. How we live and work is being transformed by CPS and other new technologies such as 3D-printing, the Internet of Things (IoT), blockchain, and artificial intelligence.

What does all this mean in practice? The Mckinsey Global Institute released a 2017 report, *Harnessing Automation for a Future that Works,* which measured the likelihood of automation in 54 countries which covered 78% of the global labor market. What they found reveals the scale of impact of 4IR. Organized by sector, the data collected show that 50% of current jobs in agriculture, forestry, fishing, and hunting, representing 328.9 million employees, are potentially automatable. For manufacturing, 64% of current jobs are automatable, representing 237.4 million current employees. For retail trade, 54% of current jobs, representing some 187.4 million current employees are automatable.[5] When considered by nation rather than industry, we see massive shifts for the world's biggest economies. McKinsey anticipates that for China 395.3 million employees are in potentially automatable jobs, making up 51% of the labor force.[6] In India, 235.1 million employees are working in automatable jobs. And in the United States 60.6 million, or 46% of the workforce, are currently in automatable jobs. Not all these jobs will go away, but all of them will be changed. As has been noted many times now, this is not just about unskilled labor. This is a story of all pattern-based and routine work being replaced. Lawyers, radiologists, architects, and accountants will all see significant changes to how they work and in some areas a much smaller demand for human labor. For example, machine learning will allow architects to deploy techniques that add complexity to the built world without cost, and robots will allow for new methods of design and fabrication doing away with traditional constraints.

Many of the new jobs that will exist even ten years from now, we cannot imagine yet. The well-paying jobs will involve creativity, data analytics, and cyber security, as there is currently a global dearth of talent in this area. What we do know is that the skills needed to take full advantage of the automation economy are different from those that have been emphasized

[5] McKinsey Global Institute, *Harnessing Automation for a Future that Works* (New York: McKinsey Global Institute, 2017).

[6] McKinsey Global Institute, *Harnessing Automation for a Future that Works.*

by HE institutions in the past. According to the WEF "Future of Jobs" report, the top ten skills that will be needed in order of priority by employers by 2020 are: complex problem solving, critical thinking, creativity, people management, coordinating with others, emotional intelligence, judgment and decision making, service orientation, negotiation, and cognitive flexibility.[7] The skills that had been identified as needed in 2015 that are no longer included in the top ten list were active listening and quality control. Cognitive flexibility and emotional intelligence were the two new skills added for 2020 to replace them. This is because as work becomes automated, it will also become much more fluid. Employees will need to be agile and able to jump between very different types of tasks and contexts. HE needs to change to better prepare thinkers of the 4IR.

Higher Education

HE has a crucial role to play in shaping the societal transitions necessary to adjust to the 4IR. But today's HE was designed to meet the needs of past industrial revolutions with mass production powered by electricity. Those systems are not suited for the automation economy. Today's students (of all ages) are faced with major challenges in demographics, population (both growing and shrinking ones), global health, literacy, inequality, climate change, nuclear proliferation, and much more. As students today leave university, the 4IR world has significantly different demands on them than have previously existed. Nearly everyone will work with artificial intelligence. What you majored in will not determine your job or your career. The content and a deep understanding of it matter, but it is also about what you are able to do with it.

The goal of most reputable institutions of HE is to develop capacity for academic achievement and retention of knowledge among graduates to prepare them for a productive life. Academic development units, commonly holding a title such as the Centre for Teaching and Learning, are preparing faculty for evidence-based practice in improving learning skills. Institutions of HE are incorporating service to community as part of their learning cultures. For example, Hong Kong Polytechnic requires all

[7] World Economic Forum, "The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution," January 2016, http://www3.weforum.org/docs/WEF_Future_of_Jobs.pdf.

undergraduates to participate in a credit-bearing service work program. And institutes of HE continue to influence policy with research-based evidence and facts. The good news is that HE has come a long way. The challenge is we have much further to go and shifts caused by climate change and 4IR make adaption imperative.

Thus far the changes in HE have been slow and inadequate, though some are trying to adapt. In the past few decades, HE has generally experienced only small incremental improvements. Better classrooms, better support, and advanced libraries. In many countries, access has widened to underrepresented groups, which offers improved social mobility. Thanks to efforts of the Millennium Development Goals to educate young girls, and better outreach from College Admissions offices, we are seeing much higher enrollment and completion by women as well. HE has also offered more diverse skills with the inclusion of experiential learning and adaptive career offices. These are all important improvements, but the 4IR requires HE institutions to depart from the current 3 or 4 year undergraduate model to prepare for lifelong learners.

Traditional, undergraduate, graduate, and research education will remain important to society, but space must be made for adult learners to continue their learning as well.[8] Institutes of HE, in collaboration with governments and industry, need to prepare lifelong learners together. The concepts, let alone the vernacular, are nearly all new. From micro-credentials, Education 3.0, nano-degrees, adaptive learning, microlearning, upskilling to the idea of preparing for just-in-time education, the message is that we must all keep learning. We must, however, caution from falling back into exclusively vocational skills-based learning through these mini-degrees and credentials. The necessary cognitive flexibility needs to be there first and the education, even if specifically targeted, needs to emphasize cognitive agility.

The response to 4IR should be a combination of liberal arts education and upskilling depending on where you are in your educational journey. Not everyone can attend a liberal arts college. But the techniques and curriculum deployed there can be adapted to a given institution's cultural and financial context. Institutes of HE can work to scaffold in the higher order thinking that is needed in the 4IR.

[8] Joseph E. Aoun, *Robot Proof: Higher Education in the Age of Artificial Intelligence* (MIT Press, 2017), 117.

Bloom's revised taxonomy of higher learning had classified six levels of learning and knowing. They are *remembering*, *understanding*, *applying*, *analyzing*, *evaluating*, and *creating*. Information transfer through the traditional lecture and test format does not get you up very high in the cognitive capacity ranks of higher order thinking. But there is also another dimension to this, what Lorin Anderson et al. in 2001 called the "Knowledge Dimension," which represents a range of knowledge from concrete to abstract.[9] The knowledge dimension is made up of facts, concepts, procedures, and metacognition. Metacognition is important because it is linked to information literacy, an essential element of intelligence in the post-truth era. Joseph E. Aoun, President of Northeastern University, in his recent book *Robot-Proof: Higher Education in the Age of Artificial Intelligence* brings these issues to bear on HE as well, making the case for content combined with cognitive capacities that revolve around systems thinking, entrepreneurship, and cultural agility.[10]

Whatever combination you apply, be it a revised Bloom's model, the WEF skills set, or an approach such as Aoun's, the bottom line is that creativity is the key. Furthermore, the learning cannot stop because the institutional progression does. Whatever was promised before by completing an HE degree is not promised any longer. High school is not enough, undergraduate education is not enough, a master's degree is not enough, and a PhD is not enough. Everyone is now responsible for lifelong learning and upskilling. It is the skills that will carry you through; the content will always be changing.

To develop these skills learning must go way beyond information transfer. HE needs to emphasize pedagogy that is student-centered and individualized. Assessments are most effective when they are grounded in project-based learning and authentic experiences. Team work also goes a long way in developing the emotional skills necessary for twenty-first-century success. Ultimately, if the students have the opportunity to conduct their own independent research through an undergraduate or graduate thesis, this allows them to create new knowledge and develop a deep understanding of how we know what we know. Quality HE in the era of the 4IR needs to incorporate these things.

[9] Lorin W. Anderson, David R. Krathwohl, and Benjamin Samuel Bloom, *Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives Abridged Edition* (Harlow: Longman, 2001).

[10] Aoun, *Robot-Proof*, xix.

Underpinning all of this are the issues surrounding gender. 4IR will impact women and men, boys and girls, differently. Females are less likely to have digital literacy, which means they will be less likely to take advantage of technological opportunities. Even for those who are fortunate enough to be participating in the technology-related workforce, women are significantly underrepresented. The reasons for this are well documented. According to the ISACA Survey, the reasons relate to a lack of mentors, a lack of female role models, gender bias, unequal growth opportunities compared to men, and unequal pay for the same skills.[11] According to the WEF Future of Jobs Survey, assuming that the current gender gap ratios persist through the 2020 period, for men there will be approximately one new STEM job per four jobs lost, but for women, for every single new STEM job created, 20 jobs will be lost.[12] That being said, the disruptions caused by 4IR present an opportunity to break away from the status quo. Throughout this book, consideration for how we can improve gender equality, and address the unique needs of men, women, and those who identify as neither, is important. Organizations like Women 2.0 and Girls Who Code are creating support on the ground in the United States. We need much more of them, and we need similar support networks for male labor groups as well. HE will need to play a role if we are going to adequately address these issues.

This book proceeds with eight chapters. The first three address major cross-cutting issues of HE in the context of 4IR. This includes Pericles Lewis's contribution on the globalization of liberal arts education, which provides an overview of the foundations of liberal arts education and the learning that it is intended to develop. Peidong Yang and Yi'En Cheng in Chapter 3 provide an important discussion of the disparities of opportunity related to HE and youth mobility. They suggest that current preoccupations with 4IR's impact on HE is colored by technocratic discourses that ignore "on the ground" experiences of the disadvantaged and marginalized. The final chapter in this section, by Lorcan Dempsey and Constance Malpas, discusses the future of the academic library in the context of electronic resources. They find that academic libraries will diverge,

[11] "ISACA Survey Identifies Five Biggest Barriers Faced by Women in Tech," ISACA, March 6, 2017, http://www.isaca.org/About-ISACA/Press-room/News-Releases/2017/Pages/ISACA-Survey-Identifies-Five-Biggest-Barriers-Faced-by-Women-in-Tech.aspx.

[12] World Economic Forum, *Future of Jobs Survey* (Geneva: World Economic Forum, 2017).

with different service bundles depending on the type of educational institution they serve. This means that the model of excellence for libraries will need to be plural, based on strategic fit to the needs of the institution they serve and not on collection size or gate count. Libraries will support research, student success and retention, community engagement, preservation of the scholarly record, and so on. But their profiles will be different depending on the particular strategic needs of their institutions.

The following four chapters look at how HE has already begun to be adapted in China, Costa Rica, Singapore, and South Africa. Rosaline May Lee and Yanyue Selena Yuan describe the state of current higher educational reform efforts in China that support innovation. They explore the obstacles facing far-reaching reform, offer a view about the likelihood of success and the potential emergence of a "Chinese model" for innovation. May and Yuan use their own experience, introducing and teaching "Design Thinking" to STEM students at a Chinese university as a case study to explore how best to develop critical thinking skills in the automation context.

Eduard Müller looks at HE through an environmental lens, applying the case study of Costa Rica's experience with learning and sustainable development. He advocates for a regenerative development approach to HE. Müller discusses three urgent challenges: the need to move from disciplinary approaches to holistic ones; adapting to disruptive technological advancements; and identifying what is truly important for survival of our civilization.

Reviewing the exciting opportunities in South Africa, Bo Xing, Lufuno Marwala, and Tshilidzi Marwala make the case for an Adopt Fast and Adapt Quick strategy for HE. Their case study presents evidence from a "smart mining" case in South Africa as implemented by the University of Johannesburg. Findings detail an adaptive solution to new demands in the HE arena, which address issues of accessibility, digital literacy, acceleration, pan-regionalization, transformation, inclusiveness, vision, and engagement of students.

Reviewing Singapore's HE systems and close government support of preparing lifelong learners, Nancy Gleason provides a detailed review of replicable policies and programs to prepare 4IR-ready citizens. Gleason details three education-based initiatives in Singapore: Smart Nation Singapore, SkillsFuture, and the creation of three new universities, in preparation for the automation economy. She details how these education-based initiatives are intended to address employment challenges in the era

of the 4IR. Developing the skills and mindset for lifelong learning is essential to making a smoother transition to the automation economy and Singapore has developed practical large-scale policies for how to do this.

The book concludes with a chapter by Bryan Penprase on the evolution of HE in the context of 4IR in the United States and around the world. He emphasizes the importance of new STEM instruction that develops technical capacities in emerging technologies in active and project-based settings. Penprase argues that a rapid adjustment of on-campus curriculum is needed. He calls for expanding STEM's capacity to accommodate the rapid acquisition of new knowledge by students, faculty, and alumni, with new modalities of instruction that leverage the digital advances from the third industrial revolution.

Evidence-based research on how we learn and new research on what skills are needed in the automation economy come together in this book. We know how to create critical thinkers, but it is not easy and it is often expensive. This book provides insights into how this is already being done in the context of 4IR around the world. We can learn from initial efforts, adapt them, improve them, and keep pushing the boundaries of learning. The automation of knowledge may be upon us, but the value of emotional intelligence combined with creativity, and working with artificial intelligence, is limitless. This is the capacity we need to foster.

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PART I

Higher Education Themes in the 4IR Context

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CHAPTER 2

Globalizing the Liberal Arts: Twenty-First-Century Education

Pericles Lewis

A liberal arts education will become increasingly important in the twenty-first century because the automation economy requires more than ever that individuals develop the cognitive flexibility and the habits of mind that allow for life-long learning. The ability to learn new skills, accept new approaches, and cope with continual social change will be essential in the fourth industrial revolution (4IR). In response to the need for a twenty-first-century liberal arts education, a partnership between Yale University in New Haven, Connecticut, United States and the National University of Singapore (NUS) developed the small and selective liberal arts institution Yale-NUS College in Singapore. The establishment of Yale-NUS College, the first of its kind in Singapore, and one of the first in Asia, indicates Singapore's commitment to life-long learning and a belief that such an education is particularly valuable in the context of the automation economy. This chapter offers some historical context for the efforts of Yale and NUS to found a new liberal arts college in Asia as well as some indications of key considerations in the broader effort to globalize the liberal arts.

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I will argue that liberal arts education attempts to shape students' characters through engagement in a shared community shaped by conversations across various disciplines and points of view.

The Founding of Yale-NUS College

Singapore, a wealthy, mostly English-speaking, former British colony, has developed in the half century since its independence an excellent educational system, including some of the best secondary schools in the world and several excellent universities. NUS, the result of a variety of mergers of earlier educational institutions, including the King Edward VII Medical College (founded 1905) and Raffles College (founded 1928), has come to be regarded as one of the best in Asia on many measures. Although it always had some distinction in the arts and sciences generally, it was mainly known in the late twentieth century for teaching engineering, medicine, and law. These professions were the main areas in which the founders of the nation wanted to invest, and the number of places at the University in various subjects is, even today, subject to central planning by the Ministry of Education (MOE). Early in the twenty-first century, NUS determined to start a program in the liberal arts.

By the late twentieth century, NUS began to rise in the rankings of research universities, around the same time that it adopted American-style tenure and academic titles (replacing the old British titles). In the first decade of the twenty-first century, the Singaporean government decided to grant its universities autonomy. In practice, the Ministry still exercises considerable control since (as in many Commonwealth countries) a large majority of the universities' budget comes from the government. But the universities have independent governing boards and can develop their own priorities, and they can raise private funds to support those priorities. In fact, the government provides generous matching funds and tax advantages to encourage private philanthropy. At the graduate and executive education level, Singaporean universities can also attract foreign students, but at the undergraduate level, the number of foreign students is capped at between 10% and 15%. This makes more places available for Singaporeans but limits the ability of the universities to become international leaders in undergraduate education. Bringing in international students diversifies the learning experience and helps build a community through conversations, fostering skill at cross-cultural communication.

Over the decade-plus since the universities were granted autonomy, NUS has been notable for its entrepreneurial attitude, forming the Yong

Siew Toh Conservatory in partnership with the Peabody Conservatory at Johns Hopkins, the Duke-NUS Medical School in partnership with Duke, the University Town residential campus, and many other impressive programs. The past President of NUS, Tan Chorh Chuan, one of the most impressive academic leaders of our time, fostered this entrepreneurial spirit. His great personal modesty did not disguise the high ambitions he held for his university. Under his leadership NUS set on a course to broaden the learning in higher education beyond information transfer. For example, the career office became the Centre for Future Ready Graduates, and the Institute for Application of Learning Science and Educational Technology was established to offer a course for all students on "learning to learn."[1]

The founding of Yale-NUS College resulted from what seems to be a typically Singaporean investment of energy and funds in a bright idea proposed by an international panel of advisors to the government. The International Academic Advisory Panel of the Ministry of Education, chaired by future Singapore President (and former NUS Vice-Chancellor) Tony Tan, recommended in January 2007 that Singapore consider founding a small private liberal arts college. In October 2007, a delegation, headed by Minister of State for Education Rear Admiral Lui Tuck Yew, visited nine small colleges in the United States, plus Northeastern University and Yale University. During the course of discussion, it was decided that rather than an independent college, the liberal arts college should form part of one of the existing universities. The then NUS Provost (now NUS President), Tan Eng Chye, presented a proposal for a liberal arts college within NUS to an MOE working group in March 2008. The university felt that such a college would have greater opportunity for success within a strong existing institution. Later that year, the proposal received approval in principle.

The proposal for a collaboration between Yale and the NUS first arose in a conversation between Tan Chorh Chuan, then President of NUS, and Rick Levin, then President of Yale, at the World Economic Forum in Davos, Switzerland in 2009. President Tan was looking for a US partner with expertise in undergraduate education. A year later, as chair of the humanities committee for the new college, I learned that many Asian universities had begun investing in a more integrative type of education, using

[1] "Education," NUS Institute for Application of Learning Science and Educational Technology, accessed January 10, 2018, http://nus.edu.sg/alset/education.html.

small classes and active learning, modeled on American liberal arts education. In November of 2017, the launch conference of the Association of Asian Liberal Arts Universities, at Lingnan University in Hong Kong, demonstrated this in full force, as dozens of institutions were represented, and 14 joined the association. Presidents Tan and Levin planned Yale-NUS College to be a pioneer of this type of education, and one of its central goals was to "foster the habits of mind and character needed for leadership in all sectors of society."[2] In this way, Singapore's MOE, and NUS, demonstrated a clear commitment to fostering habits of life-long learning in undergraduate education.

Character

The idea of a liberal education emerges from ancient times, when it described the kind of education appropriate for a free citizen, which is to say that it excluded slaves, foreigners, women, and in fact anyone who had to work for a living. We continue to work on the access to such an education today, but the liberal arts are closely aligned with freedom—the autonomy to pursue intellectual questions, the freedom to debate issues of common concern, freedoms that prepare a young person for full citizenship—even though the boundaries of that freedom have long been contested. The ancient world contrasted the liberal arts with the servile arts, that is, what we would call today vocational education. In Latin, the word "arts" refers to both the arts and sciences, and the middle ages recognized seven liberal arts: grammar, rhetoric, logic, geometry, arithmetic, music, and astronomy. Today a liberal arts education spans the arts, humanities, and social and natural sciences. When people talk about a liberal arts education, they are generally referring to undergraduate education that stresses broad study of the arts and sciences rather than pre-professional training in such subjects as business, law, medicine, or engineering. They also emphasize a collegiate form of education, in which students and faculty pursue many disciplines together in the context of a shared community, a theme addressed in the next section.

Citizenship is the most commonly cited reason to pursue a liberal education, and it is a very important one. By developing their critical reasoning skills, and by practicing the arts of discussion, collaboration, and compro-

[2] "Yale-NUS College Faculty Handbook," Yale-NUS College, last modified October 2016, https://faculty.yale-nus.edu.sg/wp-content/uploads/sites/12/2016/10/Yale-NUS_College_Faculty_Handbook-updated_Oct_2016.pdf.

mise both inside and outside the classroom, students should become better able to debate matters of public importance and to arrive at a reasoned agreement, or reasoned disagreement, with their peers in the political or civic sphere. There are at least four other good reasons to pursue a liberal education and to provide one for our young people.[3] A second reason, also valid and perhaps more significant to some parents and governments, is to shape more innovative contributors to the economy and society. This is an issue particularly important to Singapore's economic and social development. Technical education is extremely important for the development of industrial society, but in the post-industrial world, employers value softer skills such as creativity, the ability to think outside the box, and openness to multiple perspectives. Liberal education fosters these traits, and this is why liberally educated students have opportunities to join the ranks of the global elite. These skills will arguably become all the more important as artificial intelligence replaces human workers in many technical fields.

Third, certain forms of liberal education also prepare students well for life in a multicultural or cosmopolitan society by making them aware of a variety of cultures and the need to communicate effectively across cultural differences. This is done through a living and learning environment in which students must learn to engage respectfully with ideas that make them uncomfortable or with which they are unfamiliar. They learn to evaluate new ideas with evidence, and formulate opinions, not make assumptions. Fourth, and more fundamental than any of these, perhaps, is the ethical case for liberal education, the case for character. Socrates said that "the unexamined life is not worth living…."[4] Liberal education makes us aware of the importance of examining our own prejudices and assumptions by fostering habits of self-awareness and self-criticism. Finally, and most intangibly, liberal education allows the individual a greater enjoyment of life, whether it is in appreciating a work of art, understanding an argument in philosophy or an equation in mathematics, or exploring the diversity of the natural world.

[3] The list here is influenced by but not identical with that of Andrew Delbanco, *College: What It Was, Is and Should Be* (Princeton: Princeton University Press, 2014). See also my article, Pericles Lewis, "In Asia, for the World: Liberal Education and Innovation," in *Experiences in Liberal Arts and Science Education from America, Europe, and Asia: A Dialogue Across Continents*, eds. William Kirby and Marijk van der Wende (London: Palgrave, 2016), 47–60.

[4] Plato, *Five Dialogues: Euthyphro, Apology, Crito, Meno, Phaedo* (Indianapolis: Hackett Publishing, 2002), 41.

The second President of the United States, John Adams, was perhaps not the most democratic of the founding fathers, and his reputation is tainted by his enactment of the Alien and Sedition Acts of 1798. Nonetheless, his opposition to slavery, his dedication to a republican form of government—a "government of laws, and not of men"[5]—and his relationship with his remarkable wife Abigail Adams are among the reasons for his enduring appeal, which has only increased in recent decades.[6] A Harvard graduate from a modest background, Adams had a particular view of the role of liberal arts education in developing citizens for the new republic. During the debates about the US Constitution in the 1780s, he wrote that

> By gentlemen are not meant the rich or the poor, the high-born or the low-born, the industrious or the idle: but all those who have received a liberal education, an ordinary degree of erudition in liberal arts and sciences. Whether by birth they be descended from magistrates and officers of government, or from husbandmen, merchants, mechanics, or laborers, or whether they be rich or poor.[7]

In other words, Adams thought that there were certain virtues associated with being a gentleman regardless of a person's background, and that an education in the liberal arts and sciences was the prerequisite for being a gentleman in this sense. At least since the time of John Adams, one of the goals of liberal education has been cultivating character and citizenship. In Adams' time, those who received a liberal education were by definition part of a small elite, but in the nineteenth and twentieth centuries access to undergraduate education expanded rapidly. For example, Mount Holyoke was established as a liberal arts college for women in 1837, followed by several others during and after the Civil War. (Yale admitted women to graduate programs in 1869, but the college remained all-male until 1969.) This trend not only developed in America, but also in Asia,

[5] "Massachusetts Constitution," Commonwealth of Massachusetts, accessed January 10, 2018, https://malegislature.gov/Laws/Constitution.

[6] A phrase from the seventeenth-century political theorist James Harrington that Adams influentially quoted in the years leading up to the American Revolution.

[7] John Adams, *Defence of the Constitutions of Government of the United States* (Boston: Edumund Freeman, 1787). See also Gordon S. Wood, *Empire for Liberty: A History of the Early Republic, 1789–1815* (Oxford: Oxford University Press, 2009), 24. Adams' argument here was not entirely democratic: he favored a bicameral legislature in which the upper house (Senate) would represent only the educated portion of society.

for example with the establishment of the precursor to Doshisha Women's College of the Liberal Arts in 1876 in Kyoto, Japan. But early streaming regardless of more inclusive policies has remained the norm in many parts of the world. Ideally, all citizens would receive some kind of education in the liberal arts and sciences. Although American high schools have a mixed record, they do in fact pursue a broadly academic curriculum for most students and avoid the early streaming of some students into purely vocational tracks that is common in Europe and Asia.

This chapter draws on Adams' understanding of the liberal arts. Rather than argue against technical education, it is notable that liberal arts education could be strengthened by adding more of a technical dimension. At the same time, education in fields like engineering and medicine can benefit from an element of liberal education, touching on communication, ethics, and the social dimension of these technical fields. Indeed, this is particularly true in the context of the fourth industrial revolution where we are reaching new moral and ethical boundaries of what it means to be human, for example in the case of biosynthetic and artificial intelligence. Rather, here the argument is for a broad education that prepares students to lead a responsible life in this century—one that readies them for the responsibilities and privileges of freedom. An education in the arts and sciences should shape young people, regardless of their background, for life in a modern democracy. It should also help them develop character.[8]

Critics of the liberal arts come in two main types, that I would call pragmatic and ideological. Those who see themselves as pragmatists think that universities should take a more vocational approach to teaching young adults and provide them with specific skills relevant to the job market, often with a focus on science and technology. Even the 44th President of the United States, Barack Obama, whose eloquence and learning reflect the wonderful liberal arts education he pursued at Occidental College and Columbia University, offered a version of this criticism when he said that "folks can make a lot more potentially with skilled manufacturing or the

[8] For discussions of character in education, see Paul Tough, *How Children Succeed: Grit, Curiosity, and the Hidden Power of Character* (New York: Houghton Mifflin, 2012); Emily Bazelon, *Sticks and Stones: Defeating the Culture of Bullying and Rediscovering the Power of Character and Empathy* (New York: Random House, 2013); and William Deresiewicz, *Excellent Sheep: The Miseducation of the American Elite and the Way to a Meaningful Life* (New York: Free Press, 2014). On character in general, see David Brooks, *The Road to Character* (New York: Random House, 2015).

trades than they might with an art history degree"[9] (a comment for which he later apologized). Sometimes this critique is the result of a misunderstanding of the meaning of "arts"—in fact, a liberal arts education can and often does include scientific and technical education. The important question about breadth or general education is whether a broader, more interdisciplinary education really prepares students better for life. I believe that it does, and I will explain why in the third section of this chapter.

A more fundamental, ideological critique of liberal arts education takes aim at its aristocratic pedigree and sees the liberal arts as a training ground for effete elitists. The opposition results in part from a decade-plus of unequal economic growth and the sense that recent gains have gone primarily to international elites. The stagnation faced by many has also become entwined with nationalistic attitudes and resentment of perceived outsiders; people with legitimate economic and social concerns have become prey to demagogues who promise easy solutions based on an imagined simpler past. Those of us in the academy have more occasion than ever to inquire whether the kind of education we offer our students really prepares them for lives as active citizens or whether it only makes them ready for participation in a global elite typified by the consulting firms and investment banks that hire so many of our graduates. Liberal arts education should, I think, prepare students not just for success in the economy but also for democratic citizenship.[10]

Asia and the Liberal Arts

Many Asian educators and planners have felt for some time that the highly technical education they provide in their universities may have been better geared to an earlier stage of economic development. When Singapore was just beginning to industrialize, a certain number of engineers, doctors, and other professionals were required, and the government planned enrollments in the NUS accordingly. Now that Singapore is one of the wealthiest countries in the world, however, the aspirations of its citizens are more complex, and the economy has become more diverse. In this

[9] "Remarks by the President on Opportunity for All and Skills for America's Workers," The White House, last modified January 30, 2014, https://obamawhitehouse.archives.gov/the-press-office/2014/01/30/remarks-president-opportunity-all-and-skills-americas-workers.

[10] See my article, Pericles Lewis, "A Challenging Time for Cosmopolitan Education," *Times Higher Education*, February 2, 2017.

environment, preparing students for a single job for life no longer makes sense. Singaporean policymakers have come to recognize the importance of soft skills (some of the same noncognitive traits we often call character) and flexibility, while Singaporean students have sought a broader range of post-secondary educational opportunities. The increasing wealth of Singapore has also made the brain drain a reality, as more middle- and upper-middle-class families can afford to send their children to the United States, Britain, and Australia for undergraduate studies. Many of them do not return home to Singapore.

Throughout Asia in the early part of the twenty-first century, governments and private philanthropists were founding new institutions on the liberal arts model (some are listed below). They worried that the United States, despite its 15-year-olds' limitations in test-taking, had produced greater innovation than Asian societies.[11] Many advocates of liberal education believe that it is the American post-secondary education system (rather than, say, corporate governance, tax structures, or immigration policy) that accounts for the success of our brands and especially our technology companies. Shortly before his death in 2011, Apple founder Steve Jobs had said "It is in Apple's DNA that technology alone is not enough. It [is] technology married with Liberal Arts, married with the Humanities, that yields us the results that make our heart sing."[12] Asian educators saw that while their students had excelled in cognitive tests and in exams at the end of high school, their universities failed to encourage innovation and lacked some of the opportunities of the American higher education system. To some extent, as the quotation from Jobs suggests, these opportunities are curricular, but more fundamental than the curriculum was the effort to foster character, to allow students to develop more holistically. Jobs understood, as other entrepreneurs do, that to thrive in the fourth industrial revolution, you need to be able to learn new things, constantly, and to draw connections between apparently disparate areas of endeavor.

[11] Richard C. Levin, "Top of the Class: The Rise of Asia's Universities," *Foreign Affairs* 89, no. 3 (May/June 2010).

[12] Quoted in Anthony Woodcock, "The Death of Liberal Arts? Or the Reunion of Broken Parts," *Huffington Post*, April 25, 2015. For further consideration of the liberal arts and the fourth industrial revolution, see Daniel Araya and Creig Lamb, "Surfing the 4th Industrial Revolution: Artificial Intelligence and the Liberal Arts," *Brown Center Chalkboard*, April 11, 2017, https://www.brookings.edu/blog/brown-center-chalkboard/2017/04/11/surfing-the-4th-industrial-revolution-artificial-intelligence-and-the-liberal-arts/.

The mission statements of the new Asian programs show this combination of an idealism about character education and faith in the American liberal arts model. Yuanpei College, founded in 2001, at Peking University (one of the leading universities in China, founded in 1898) proclaims an "emphasis on fundamental studies, practical capability and personal character."[13] The School of International Liberal Studies (2004) at Waseda University in Tokyo (1882) aims to nurture "truly global citizens motivated to act on the world stage by a sense of justice, competitiveness, and humanity."[14] The College of Liberal Studies (2009) at Seoul National University (1946) hopes "to achieve its aim of cultivating dedicated and competent leaders of the global community … through giving students the freedom to choose [their course of study]."[15] Ashoka University, outside Delhi, newly founded in 2011, wants "to help students become well-rounded individuals who can think critically about issues from multiple perspectives, communicate effectively and become leaders with a commitment to public service."[16] Although the similar rhetoric of so many university and college websites can induce a certain amount of cynicism, in fact the widespread efforts of these and many other new programs in Asia point to a desire on the part of universities to move beyond simple success on tests. They also respond to demand: Asian students thirst for an education that will address their desires for justice, service, and self-expression. They also want to develop the noncognitive skills that will allow them to be successful in a globally competitive job market—a job market, that for Asia, is likely to be automated sooner than in other parts of the world.

The secondary education system in Singapore is generally judged to be one of the best in the world, and Singaporean students score near the top internationally in tests like the Programme for International Student Assessment (PISA), which tests 15-year-olds' achievements in reading, math, and science, and in the British A-levels and the International

[13] Quoted in Chang Chenguang, "Introducing English-Language Liberal Education in China," in *International Teaching and Learning at Universities*, eds. Gordon Slethaug and Jane Vinther (New York: Palgrave Macmillan, 2015), 38.

[14] "School of International Liberal Studies," Waseda University, accessed January 10, 2018, https://www.waseda.jp/fire/sils/en/about/overview/.

[15] "Seoul National University College of Liberal Studies," Yale-NUS College, accessed January 10, 2018, http://international-liberal-arts.commons.yale-nus.edu.sg/east-asian-liberal-arts-institutions/seoul-national-university-college-of-liberal-studies/.

[16] "About Ashoka University," Ashoka University, accessed January 10, 2018, https://www.ashoka.edu.in/pages/about-us-69.

Baccalaureate (IB). But Singaporeans have been aware for some time that success on tests does not necessarily translate directly either into good employment opportunities or for that matter into happiness. The high schools have gradually moved away from rote memorization and test prep and toward more active learning approaches. In his 2012 National Day Message, the Prime Minister, Lee Hsien Loong, argued for a more holistic form of education: "Let us prepare every child for the test of life, not just a life of tests."[17] This has been further fostered not just by the development of Yale-NUS College, but also by investments in life-long learning through such programs as FutureSkills Singapore and SingaporeInnovate.

Some writers on education argue that schools, colleges, and universities have given up on the goal of shaping their students' characters.[18] In a society with many competing views about virtue, and one where students and their parents are often seen as clients or customers, it is easier for educational institutions to remain neutral about anything that touches on values and to demand less from their students. The right tends to blame educational institutions for being too permissive and not, for example, guiding students on proper sexual mores. The left blames those same institutions for transmitting the values of a dominant society that it views as inegalitarian or even oppressive. Critics on the right would have the university speak more explicitly about moral values. Critics on the left would have us more explicitly question the social and political values of the dominant society. In this context, even talking about character can seem prudish or quaintly Victorian.

And yet, educators want to transmit values to the next generation. The values to be transmitted vary greatly. Some may want to teach rigorous scientific method; others a particular set of theories about society or notions of justice; still others a set of esthetic responses to the world. But in all these cases the underlying concern is to shape students' characters, to make them in a broad sense better people. Educators understand that the desire for knowledge, curiosity, is central to the development of character. It is not just the old injunction, know thyself, that was engraved on the entrance to Apollo's Temple at Delphi. It is also a matter of knowing

[17] "Prime Minister's National Day Message: Full Speech," *The Straits Times*, August 8, 2012, http://www.straitstimes.com/singapore/prime-ministers-national-day-message-full-speech.

[18] Deresiewicz, *Excellent Sheep*; Harry Lewis, *Excellence Without a Soul: Does Liberal Education Have a Future?* (New York: PublicAffairs, 2007).

the world—that curiosity about the world helps us to understand how we relate to what is on the next block or the other side of the planet and thereby also helps us to understand how we relate to other individuals and other cultures. In the pursuit of knowledge about the world we also come to know ourselves better.

The Chinese refer to liberal education as "whole-person education." It is recorded in the Analects of Confucius that "The Master said: The gentleman [junzi] is not a vessel [qi]," where Chin Annping explains that "a gentleman, junzi (君子), is broad of spirit and intellectually agile; he can take on different problems and apply himself to many situations and so is not a vessel, a qi (器), for a specific use."[19] One source for the recent surge of interest in liberal education is the sense that the relatively narrow, technical education that has predominated in Asian universities does not prepare students well for the complexity of the modern world and economy. But a deeper source of concern is the sense that mere technical education does not help students develop character, does not shape gentlemen in Confucius' sense. Some of the liberal education movements have aimed to inculcate Confucian values, as perceived by modern Asian governments, and (at least in their interpretations) such values in fact strongly contrast with modern Western liberal values. But the most promising experiments, not only in Singapore but also in China, Hong Kong, and South Korea, expose students to a variety of both Asian and Western ideas about character and allow the students to form their own judgments, whether they be gentlemen or ladies.

In all character education, the teacher's role as an example is essential. Mencius, the most famous follower of Confucius, said in the fourth century BCE

> A gentleman teaches in five ways: the first is by a transforming influence like that of timely rain. The second is by helping the student to realize his virtue to the full. The third is by helping him to develop his talent. The fourth is by answering his questions. And the fifth is by setting an example others not in contact with him can emulate. These five are the ways in which a gentleman teaches.[20]

[19] Confucius, *The Analects*, trans. Chin Annping (New York: Penguin Books, 2014), 17–18.

[20] D. C. Lau, *Mencius* (Hong Kong: Chinese University Press, 1979), 2: 283.

A Chinese liberal arts professor once told me his goal was to train people to be noble or better persons. We may all disagree on what constitutes nobility or what it means to be a gentleman or lady or even a good person. Some of us may doubt whether it is possible to have much influence on people's characters by the time they get to university. But I think that anyone who decides to become a teacher would agree that, underlying the subject matter, methodological debates, or political ideologies, the ultimate goal of education is to make young people better. Ideally, we can help them learn to shape their own characters to the point where, at least within the limits of circumstance, they can also choose their own fates, and have the habits of mind to adjust their knowledge to the societal context.

Community

While schools, colleges, and universities help to form their students' character, they do not do so through a simple exchange between an individual teacher and a single student. They shape their students through their engagement in a community. The philosopher John Dewey, the leading influence on progressive education in the United States, wrote that "the school is primarily a social institution … [and that] the child should be stimulated and controlled in his work through the life of the community."[21] Colleges, in particular the residential colleges typical of American higher education, provide a special kind of community that students inhabit for four years of transition between adolescence and adulthood. American educators have used the term a "community of learning" to describe the function of such colleges, which ultimately derive their form and often their architecture from the cloistered monasteries of medieval Europe, and they often maintain the air of the cloister for better and for worse.

The first residential colleges were constructed at Oxford in the thirteenth century for students at the university there. The essential character of college life is the attention we pay to the needs of a group of friends and classmates who learn together and who teach one another.[22] This living and learning environment enables what social scientists call the peer effect.

[21] John Dewey, "My Pedagogic Creed," in *The Continuing Debate: Essays on Education*, eds. Leslie A. Fiedler and Jacob Vinocur (New York: St. Martin's 1964), 172, 174. Dewey did not make a strong distinction between society and community.

[22] "Groundbreaking Ceremony of Yale-NUS College: A Community of Learning," Yale-NUS College, July 6, 2012, https://www.yale-nus.edu.sg/newsroom/groundbreaking-ceremony-of-yale-nus-college/.

It is something professors sometimes neglect to acknowledge, namely that students can—in the right environment—learn as much from their interactions with each other in student societies and team sports, and from intense late-night conversations, as they do from their formal course work. While the American collegiate model traces its roots to medieval Oxford and Cambridge, similar communities of learning existed in China and India even earlier. At the Temple of Confucius in Beijing, built in 1302, the 13 Confucian classics are inscribed on steles and the names of the scholars who scored highest in the imperial exams are preserved on stone tablets.[23]

Many committed educators see a split in the purpose of college arising out of the growth of the research university in the late nineteenth century, a point made with great subtlety by Andrew DelBanco in his book *College*.[24] The Ivy League colleges all began life before the American Revolution as undergraduate-only institutions, and in fact students often enrolled at the age of 15 or 16. It was only with the rise of science and social science and the importation of graduate education, mostly on a German model, that these colleges became universities, in a sense adding a whole research apparatus on top of their traditional undergraduate programs—and transforming those programs in the process. Dartmouth, in fact, still calls itself a college, and the other Ivy League universities became more or less research-intensive, with Harvard perhaps the most tilted toward graduate and professional education while others like Princeton and Brown remained relatively more focused on undergraduates in the United States.

Around the same time, in the late nineteenth century, new universities like Johns Hopkins (1876), the University of Chicago (1890), and Stanford (1891) were founded on the research-intensive model. Meanwhile, hundreds of small colleges, often founded by religious denominations, maintained their focus on liberal arts education for undergraduates only. In general, the older colleges and those located in wealthy cities (which, in the nineteenth century, included New Haven, Connecticut) tended to grow into universities, while those in more out-of-the-way

[23] On the history of Chinese higher education, see T. H. C. Lee, *Education in Traditional China: A History* (Boston: Brill, 2000).

[24] Delbanco's book tells something of the history of American liberal arts colleges, including Harvard, Yale, and Columbia, in the pre-revolutionary era. See also Bryan Garsten et al., *Yale-NUS College: A New Community of Learning* (New Haven: Yale University, 2013).

places or with somewhat shorter histories remained liberal arts colleges. Many of the large universities, however, maintained a strong emphasis on undergraduate education.

An early encounter between the liberal arts tradition and modernity resulted in one of the most influential educational documents of the nineteenth century, the Yale Reports of 1828. Other colleges, notably Amherst, were considering dropping the requirement for Latin and Greek, and the Yale trustees asked a faculty group, led by President Jeremiah Day, to consider reforms to the curriculum. The first section of the resulting report, written by President Day himself, offers a strong defense of liberal education, mostly along traditional lines but with important innovations. What seems to have been relatively innovative, and become a standard part of most subsequent defenses of liberal education, was Day's emphasis on teaching students "how to learn."[25] In particular, Day argued in what became a famous passage that

> The two great points to be gained in intellectual culture, are the discipline and the furniture of the mind; expanding its powers, and storing it with knowledge. The former of these is, perhaps, the more important of the two … Those branches of study should be prescribed, and those modes of instruction adopted, which are best calculated to teach the art of fixing the attention, directing the train of thought, analyzing a subject proposed for investigation; following, with accurate discrimination, the course of argument; balancing nicely the evidence presented to the judgment; awakening, elevating, and controlling the imagination; arranging, with skill, the treasures which memory gathers; rousing and guiding the powers of genius.[26]

What was distinctive about the Yale Reports was the emphasis not on the teaching of traditional subject matter (although the second part of the document does defend classics) but on the development of the student's mental powers, "the resources of his own mind."[27] The reports in fact used most of the arguments in favor of liberal education that educators do today—the political (citizenship), economic, cultural, ethical, and esthetic—and, as the historian Jack Lane has shown, they do so in service of a relatively modern, liberal capitalist notion of the autonomous

[25] Yale University, *Reports on the Course of Instruction in Yale College: By a Committee of the Corporation and the Academical Faculty* (New Haven: Hezekiah Howe, 1828), 14.
[26] Yale University, *Reports on the Course of Instruction in Yale College*, 7.
[27] Yale University, *Reports on the Course of Instruction in Yale College*, 8.

individual who contributes to society through his economic activities as much as through politics or religion.[28] Lane notes that the report nowhere uses the word *virtue*, a more traditional and morally loaded term for education[29]; it does, however, frequently emphasize *character*, with its implications of self-reliance and entrepreneurship, appropriate for the rapidly expanding American economy. Day emphasizes also that all social classes should have a liberal education, given "[o]ur republican form of government."[30] Despite their curricular conservatism, the Yale Reports took a clearly progressive political view in their justification of the curriculum. The Yale Reports had a major influence on the curriculum in many of the 80 or so colleges founded in the United States in the first half of the nineteenth century, a significant number of which were led by Yale graduates or former Yale faculty.

In the later nineteenth century, as the research ideal gained ascendancy, Harvard President Charles William Eliot moved his university away from the common curriculum and introduced the elective system for undergraduates. Eliot argued in his inaugural address of 1869 that "the young man of nineteen or twenty ought to know what he likes best and is most fit for."[31] The rise of the elective system was part and parcel of the transformation of liberal arts colleges into research universities, as both professors and students became more specialized. It may also have reflected a new idea of young adulthood as many of Eliot's students had fought in the war and the average age and maturity of undergraduates rose notably. Beginning in the late nineteenth century, most American universities allowed students to choose most of their own courses and required them to specialize in one major subject, while often creating distributional requirements that required them to study at least some subjects outside their own major field. Eventually Yale too dropped the Latin and Greek requirements and started to allow students to choose most of their own courses and to major in a specific discipline. Training in a major (or concentration at Harvard) resembled preparation for a PhD more than it did the old unified curriculum of the early nineteenth century. This breaking up of the old systems of knowledge and replacement of traditional subjects

[28] Jack C. Lane, "The Yale Report of 1828 and Liberal Education: A Neorepublican Manifesto," *History of Education Quarterly* 27, no.3 (1987): 337.

[29] Lane, "The Yale Report of 1828 and Liberal Education," 334.

[30] Yale University, *Reports on the Course of Instruction in Yale College*, 29.

[31] Elliot, *Addresses at the Inauguration of Charles William Elliot as President of Harvard College, Tuesday, October 19, 1869* (Cambridge: Server and Francis, 1869), 39–40.

by modern, late nineteenth-century ones reflected the impressive growth of science and the social sciences as well as a more fundamental change in the attitude to the purposes of undergraduate education, with an increased emphasis on specialization.

Residential colleges continue the work of liberal education beyond the classroom, promoting compromise over unilateral decision-making and a recognition of others' humanity and worth over the primacy of a single student's individual needs. Students learn to become leaders among their peers, but also learn to listen to what their peers have to say, forging and evaluating solutions together. Particularly in today's multicultural society, by living alongside peers with a variety of different backgrounds, experiences, and interests, students learn to coexist with others, even in situations where their opinions or expectations may differ widely from one another.[32] As the connectedness of the social media and the internet of things brings us all closer together, these skills increase in value.

Conversation

Ultimately the challenge of designing a curriculum for a cosmopolitan and multicultural college relates to the problem of meaning in a secular age. In his early twentieth-century lecture on "Science as a Vocation,"[33] the sociologist Max Weber quotes the novelist Leo Tolstoy to the effect that the essential question for all of us is "what shall we do and how shall we live?"[34] Weber argued that the modern age is one of disenchantment, in which we no longer believe that the world itself has an essential meaning.[35] For Weber, this also led to a somewhat pessimistic assessment of the possibilities for education. Since science, and learning more generally, is continually expanding, it is impossible for any one of us to command more than an infinitesimal fraction of all the knowledge that is out there in the world. Furthermore, whatever scientific discoveries we make today are destined to be surpassed in just a few years. For Weber, this meant that modern life lacked the sense of meaning that life in a more traditional

[32] On the importance of avoiding self-segregation in university accommodation, see Lewis, *Excellence without a Soul*, 79.

[33] Max Weber, "Science as a Vocation," in *Max Weber's Complete Writings on Academic and Political Vocations*, trans. Gordon Wells, eds. John Dreijmanis (New York: Algora Publishing, 2007), 25–52.

[34] Max Weber, "Science as a Vocation," 39.

[35] Weber, "Science as a Vocation."

society, whose mores and intellectual presuppositions were not constantly changing, could supply. Weber recognized, however, that even while scholarship could not necessarily solve the problem of how to live, the scholar as teacher did have a responsibility to his or her students. That duty, the college teacher's duty, is not to tell students what they should do with their lives, how they should live, but it is to confront students with what Weber called "inconvenient facts,"[36] that is, facts that may challenge their preconceived opinions. This is not to say that we should only present the facts that support our own opinions—far from it, if we are doing our job right we will also present facts that challenge what we ourselves hold dear. Weber summarizes the task of the educator as follows: "we can force the individual, or at least we can help the individual, to give himself an account of the ultimate meaning of his own conduct."[37] In other words, our task is to require students to clarify their own answers to the questions "what shall we do and how shall we live?" We cannot answer the questions for our students, but we can ask young people to confront them. As artificial intelligence replaces humans in many jobs, what livelihoods will be human? These questions are essential for civic leaders to ponder and respond to as the way we live and work is altered. In this way, a liberal arts education prepares communities for the adjustments ahead.

The goal at Yale-NUS College was to create a more integrative type of curriculum that would truly prepare students for an engaged and intellectually enriching life. I phrased the challenge of the Yale-NUS curriculum in terms of a central question: What must a young person learn in order to lead a responsible life in this century? The story of how the Yale-NUS curriculum developed is essentially a conversation about conversations, and I believe it has some value for thinking about how we educate young people to be open-minded participants in the conversations of today and even to enter into conversation with the great traditions of the past. These are the kinds of conversation that Plato and his friends held in the academy, the grove of olive trees in Athens that gives its name to modern academia. The great painting by Raphael, The School of Athens, in the Vatican, imagines the thinkers of many centuries in a conversation, with Plato and his student Aristotle at the center. This was the kind of conversation we wanted our students from all over the world to participate in, but what would an Athenian-style education look like today?

[36] Weber, "Science as a Vocation," 43.
[37] Weber, "Science as a Vocation," 48.

Since classical times in the West, as I mentioned above, a liberal education has been understood to mean the type of learning appropriate for a free citizen. In the ancient world, these citizens were exclusively male and often held slaves; even Athenian democracy was hardly democratic by modern standards. Nonetheless, over time, and notably in the early days of the American republic, liberal arts also became part of an education for democratic citizenship, and even earlier education has generally had an element of meritocracy or democracy about it, insofar as it allowed the most talented to rise regardless of rank and connections. This was the motivation behind the great Asian examination systems, and in fact Asia had its own forms of liberal arts education. The seven liberal arts of medieval Europe comprised the trivium (grammar, logic, and rhetoric) and the quadrivium (arithmetic, geometry, music, and astronomy), while in China, from the time of Confucius onward, the six arts that defined a gentleman were rites, music, archery, charioteering, calligraphy, and mathematics. There is considerable overlap here with the West, although the Chinese seem to have prized military accomplishments more highly. In both Asia and the West, what we today think of as sciences were part of the liberal arts from the beginning.

The plan for the curriculum at Yale-NUS College was to draw on the great traditions of both Asia and the West, and to establish a conversation among them. Our ideal of forming a well-rounded person capable of taking on challenges from multiple perspectives would be recognizable to educators of earlier generations in China as well as Greece. Nonetheless, these traditions have been very broadly transformed by the forces known as modernity. This is another word for the same set of forces that Weber described as responsible for the "disenchantment of the world."[38] Modernity means that rather than living in organic face-to-face communities we live in larger, more impersonal societies. It also undermines our consensus about what kind of character should be admired. These forces also mean that there is less consensus than there once was about the curriculum or what the curriculum really represents, the knowledge every educated person must have.

One of the most telling criticisms of the liberal education provided at American colleges and universities ever since the development of the elective system has been that it caters to student desires or fads and does not demand enough of them. There is some truth to this complaint, although much

[38] Weber, "Science as a Vocation," 35.

depends on the attitude of the students, since the elective system allows them so much leeway. The former Dean of Harvard College (from 1995 to 2003), Harry Lewis (no relation), argues that systems based on distribution requirements provide "the easy way out of the imperative for general education … for both students and faculty [since] professors can teach from their home bases and yet take credit for contributing to the breadth of undergraduate education [while students can] treat curricular requirements as the rules of a game they are challenged to win, seeking out the easiest course in each division."[39] As a result, such relatively weak general education requirements, and an obsession with grades, may undermine some of the purposes of liberal education and may also exacerbate the divide between the humanities and the sciences, as students from one division try to get away with the least possible work in the other.

In the end, the new Yale-NUS faculty created a comprehensive curriculum based on conversations between Asia and the West, which has been one of the hallmarks of the college and broadly popular among students and applicants.[40] One of the main goals was to bridge the gap between the sciences and the social sciences, to bring STEM into the fold to make it STEAM. Given the diversity of preparation of our students and the cumulative nature of scientific subjects, designing a common course in science was a particular challenge. We decided to focus on the process of scientific inquiry—how are scientific theories developed and proved, what evidence counts, and how have these standards developed over time. The first few times we taught the science courses we experienced the challenge, more forcefully than in other fields, of trying to teach a broad approach to the nature of scientific knowledge when the knowledge base was quite uneven. In other words, it would be easier to teach the scientific discipline of the mind if all the students had the same scientific furniture. After reviewing the entire common curriculum in the college's third year of operation, we came up with an approach that emphasized one big question in each semester of the scientific inquiry course. One semester would approach the question *how do we know that the theory of evolution is true and accounts for the development of the human species?* The other would ask *how do we know that climate change is happening and how do we predict its impact?* These broad questions, while taking in many questions of basic science and the history and philosophy of science, also lend themselves to exploring

[39] Lewis, *Excellence Without a Soul*, 50.
[40] Garsten et al., *Yale-NUS College*.

current, cutting-edge techniques. They also have obvious social importance and inherent significance.

There are legitimate questions about whether a core or common curriculum is the best form of liberal education, as against the elective systems more common in American colleges and universities. I think it is the right approach at Yale-NUS because it creates unity of experience among a very diverse group of 250 students per year from over 40 different countries and because, being very selective, we can count on students' ability to manage the challenges of the common curriculum. As such, the diversity, the small class size (capped at 18 students), and the selectivity make this approach feasible. It also helps that we do not assign recorded grades in the first semester so students have some time to adjust to the rigors of college, developing skills in how to learn, rather than how to earn an A.

Our common curriculum is our answer to the question of what a young person must learn—for this time and place—and we recognize that the answer in a different college might be different. But more importantly, we expect that our students will specialize—we just want them to specialize a year or two later than they do elsewhere. Specifically, we are trying to reset the balance between the disciplines that were mostly founded in the nineteenth century and that are the central organizing principle of most modern research universities, and the broad learning that we think, even today, will form the best basis for a student's future encounters with the world. The original designers created 14 majors across three divisions, sciences, social sciences, and humanities. The faculty members who support these major programs can speak to a vast breadth of literature, history, and quantitative reasoning. In this way, they model the character and citizenship the college intends to foster in our students.

In the end, the argument for a common curriculum is closely linked to the notion of college as a community of learning. Clearly there are some things a young person must learn, and just as clearly not all those things are taught in high school. In a global college like Yale-NUS in Singapore, but even in a diverse community like the United States, despite the efforts to achieve a common core in high school, students come to college with very different levels and types of preparation, and ideally a common curriculum will allow us to ensure that they graduate with some of the essential skills and civic knowledge that cannot be guaranteed in a pure elective system and that may not be included in their majors.

There is pressure everywhere for education to be more technically or vocationally focused. The case made here is that history has created a

model of education that develops the whole person, to yield critical thinkers who know how to learn and accept that necessity as inevitable. In the automation economy, the most valuable education will come from colleges and universities that can teach students how to learn. The example of the US higher education system in the past century and a half is one in which students have been allowed to study broadly, providing a community in which creativity and active learning can thrive. The forces of globalization are spreading this approach further still. The establishment of Yale-NUS College in Singapore is a strong example of the thoughtful way in which Asian nations are opening up such opportunities for their citizens. This will make them all the more prepared for the impacts of the fourth industrial revolution and enable them to live fuller lives.

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CHAPTER 3

Educational Mobility and Transnationalization

Peidong Yang and Yi'En Cheng

Introduction

The concept fourth industrial revolution (4IR) currently generates perhaps as much excitement as it does vagueness and ambiguity. Coined by Klaus Schwab,[1] and promulgated through the highly influential World Economic Forum (WEF) he founded, 4IR appears to be the next big idea about world technological and economic development. According to Schwab, the 4IR is 'building on the Third, the digital revolution that has been occurring since the middle of the last century. It is characterized by a fusion of technologies that is blurring the lines between the physical,

[1] Klaus Schwab, *The Fourth Industrial Revolution* (New York: Crown Publishing Group, 2017).

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digital, and biological spheres.'[2] Despite its being built on the third industrial revolution (3IR), Schwab maintains that the 4IR is not merely an extension or prolongation of its predecessor, but is a distinct phase distinguished by the extraordinary *velocity*, *scope*, and *system impacts* of its technological advancements. In more concrete terms, Schwab identifies artificial intelligence (AI), robotics, the internet of things (IoT), autonomous vehicles, 3D-printing, nanotechnology, biotechnology as some of the key technological drivers of the 4IR; in addition, he also highlights disruptive impacts of emerging business models such as 'sharing' or 'on demand' economy (with perhaps the most iconic examples being AirBnB and Uber).[3]

It is argued that this burgeoning 4IR will have far-reaching and profound consequences for all actors in today's globalized world: businesses, governments, and people.[4] However, what exactly these consequences will be remains unclear and essentially a matter of speculation. Considerations of the changing nature of employment and skills are often prominent within existing discussions about 4IR. If one takes a *functionalist* view that education primarily serves to equip members of society with the right qualities and skills to function in the prevailing socio-economic conditions,[5] then such considerations can also be regarded as implicitly about education and training. For example, when writing about the opportunities and challenges associated with 4IR, Schwab asserts that talent will represent the critical factor of production, leading to a job market increasingly segregated into 'high-skill/high-pay' and 'low-skill/low-pay' segments, with the middle hollowed out. Implicitly, then, education and training in the 4IR-shaped future should aim to develop in learners high-level, high value-adding skills.[6] A similar narrative is found in the Asia Pacific Economic Cooperation (APEC) Education Strategy Action Plan, which endorses multilateral cross-border collaboration between universities

[2] Klaus Schwab, "The Fourth Industrial Revolution: what it means, how to respond," January 14, 2016, https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/.

[3] Schwab, *The Fourth Industrial Revolution*.

[4] Schwab, "The Fourth Industrial Revolution."

[5] Randall Collins, "Functional and Conflict Theories of Educational Stratification," *American Sociological Review,* 36, no. 6 (1971): 1002–1019.

[6] Schwab, "The Fourth Industrial Revolution."

within the region, so as to deliver skills required to produce graduates who can navigate the 4IR.[7]

In this chapter, we are interested in the relationships between (higher) education, mobility, and the 4IR. We question whether and to what extent higher education (HE) has been transformed by 4IR. Furthermore, we consider whether these transformations are contributing to changing structures around educational inequality and social justice or reproducing them. We engage with these questions by drawing on our respective research on HE mobility and transnationalization in the context of Asia. We view education from a *critical* and loosely speaking *culturalist* perspective. By critical we mean that in our work we maintain a critical distance from, and a skepticism of, certain hegemonic discourses and imaginaries about education and educated persons. Instead, we pay attention to relations, practices and subjectivities of power, domination, inequality, and injustice manifested in specific educational contexts. By a culturalist perspective we mean that we treat education as a socio-cultural domain that cannot be adequately understood without being sensitive to the local social and cultural contexts to certain educational projects or configurations and attending to the cultural and subjective dimensions in educational experiences in terms of meaning-making, narratives, values, desires, and aspirations.

We adopt such a critical and broadly speaking culturalist perspective as opposed to a functionalist one not only because the former is integral to our empirical research, but also for two additional reasons. First, as evidenced in existing 4IR literature about education and training, a functionalist perspective tends to result in a kind of futurologist discussion that comprises half speculation and half prescription, both divorced from empirical observations from the ground. Secondly, our research has led us to view educational systems and configurations (such as international mobility and transnationalization) as outcomes of enduring power relations that act and interact on multiple scales: global, national, institutional, community, and individual. Because of this complex socio-cultural constitution of educational phenomena, we are somewhat skeptical of any straightforward idea about HE being transformed as a result of the alleged onset of the 4IR, especially with respect to education's role in social and cultural reproduction. Instead, with our studies depicting significant recent

[7] Yojana Sharma, "Universities can help overcome economic nationalism," November 23, 2017, http://www.universityworldnews.com/article.php?story=20171123200015564.

trends in HE in the Asian context, we aim to shed light on the various social forces, interests, and contextual factors shaping HE in the first two decades of the twenty-first century. Our basic assertion is that such an understanding will continue to be valid for the near future, and thus provide a solid ground for pondering the new changes 4IR may bring to HE.

In the remaining sections, we discuss two contemporary educational phenomena that are undergoing profound intensification, namely international student mobility (ISM) and emergence of transnational higher education (TNHE) industry in the context of Asia. We then illustrate both phenomena through two cases. The first case consists of a recent form of intra-Asia student mobility involving Indian youths heading to China for English-medium Bachelor of Medicine and Bachelor of Surgery (MBBS) degrees. The second case concerns transnational education programs offered by private institutes in the city-state of Singapore. In the chapter's concluding section, we sum up the main insights emerging from our two cases, and offer these as the basis for an alternative and more critical direction for understanding the complex relationships between 4IR and HE.

Educational Changes in a Contemporary Asian Context: International Mobility and Transnational Higher Education

International Student Mobility

In tandem with the intensification of globalization, ISM in HE has undergone significant expansions over the past decades. The number of students enrolled in tertiary education outside their countries of citizenship grew from 1.3 million in 1990[8] to an estimated 5 million in 2014.[9] With the world now poised to enter the 4IR era, ISM is set to continue to grow: it has been projected that by 2025 there will be 8 million HE international students in the world. Importantly, while so far ISM has predominantly

[8] OECD, "Education Indicators in Focus – 2013/05 (July)," 2013, http://www.oecd.org/edu/skills-beyond-school/EDIF%202013--N%C2%B014%20%28eng%29-Final.pdf.

[9] ICEF Monitor, "The state of international student mobility in 2015," November 5, 2015, http://monitor.icef.com/2015/11/the-state-of-international-student-mobility-in-2015/.

involved student flows from Asia to the Anglophone West,[10] the rise in student mobilities within Asia has caught scholarly attention more recently.[11] According to UNESCO, in 2016 the East Asia and Pacific region already hosted 19% of the world's international students, trailing only behind North America and Western Europe.[12] The case of Indian youths being attracted to earn their MBBS degrees in China provides an interesting lens for examining this rising trend of intra-Asia student mobility.

As a multifaceted phenomenon, ISM has been approached from various theoretical perspectives in literature.[13] One of the most analytically productive ways to understand ISM is through a Bourdieusian lens focused on different forms of capital[14] and their mutual conversion as a mechanism of class re/production. ISM is analyzed as a way of accumulating *cultural capital* which is subsequently reconverted into employability, status, social networks to facilitate the reproduction of class advantage.[15] Johanna Waters's work on Hong Kong students saliently highlights how

[10] UNESCO, "The International Mobility of Students in Asia and the Pacific," 2013, http://unesdoc.unesco.org/images/0022/002262/226219E.pdf.

[11] Sheng-Ju Chan, "Shifting Patterns of Student Mobility in Asia," *Higher Education Policy* 25, no 0.2 (2012): 207–224; Francis L. Collins, "Regional Pathways: Transnational Imaginaries, Infrastructures and Implications of Student Mobility within Asia," *Asian and Pacific Migration Journal* 22, no. 4 (2013): 475–500; Christopher Ziguras and Grant McBurnie, "International Student Mobility in the Asia-Pacific: From Globalization to Regional Integration?," in *Higher Education in the Asia-Pacific*, ed. Simon Marginson, Sarjit Kaur, and Erlenawati Sawir (Netherlands: Springer, 2011), 123–140.

[12] UNESCO, "Global Flow of Tertiary-Level Students," 2016, http://www.uis.unesco.org/Education/Pages/international-student-flow-viz.aspx (site discontinued).

[13] Russell King et al., "Reproducing advantage: the perspective of English school leavers on studying abroad," *Globalisation, Societies and Education* 9, no. 2 (2011): 161–181.

[14] Pierre Bourdieu, "The Forms of Capital," in *Handbook of Theory and Research for the Sociology of Education*, ed. John G. Richardson (London: Greenwood Press, 1986), 241–260.

[15] Vladimír Baláž and Allan M. Williams, "'Been there, done that': international student migration and human capital transfers from the UK to Slovakia," *Population, Space and Place* 10, no. 3 (2004): 217–237; Allan M. Findlay et al., "World class? An investigation of globalisation, difference and international student mobility," *Transactions of the Institute of British Geographers*, 37, no. 1 (2012): 118–131; Russell King and Enric Ruiz-Gelices, "International student migration and the European 'Year Abroad': effects on European identity and subsequent migration behavior," *International Journal of Population Geography* 9, no. 3 (2003): 229–252; Johanna Waters, "Geographies of cultural capital: education, international migration and family strategies between Hong Kong and Canada," *Transactions Institute of British Geographers* 31, no. 2 (2006): 179–192; Johanna Waters, *Education, Migration, and Cultural Capital in the Chinese Diaspora: Transnational Students between Hong Kong and Canada* (New York: Cambria Press, 2008).

cultural capital is accrued *transnationally*, sometimes by students who are otherwise excluded from first-choice local universities in their home country/territory.[16] In this sense, studying abroad also functions as a 'second chance'[17] strategy for certain student populations in highly competitive educational systems—a point that resonates with the case of transnational education (see below).

It is worth noting that although there has been an implicit assumption that internationally mobile students tend to be privileged socio-economically,[18] increasing evidence shows this is not necessarily the case.[19] For youths from not-so-privileged backgrounds, studying abroad could be:

1. a way to bypass local barriers to education—financial and/or academic—and to get a 'second chance' at realizing their aspiration for social mobility through training in certain professions that are believed to promise such;
2. a step toward immigration to a more desirable country or place that promises higher wages and/or a greater sense of international mobility.[20]

Thus, pursuing educational mobility is seldom about education/learning per se, but is often deeply embedded in specific social contexts and motivated by socio-culturally shaped desires and imaginaries.

[16] Waters, Education, Migration, and Cultural Capital in the Chinese Diaspora.

[17] Rachel Brooks and Johanna Waters, "A Second Chance at 'Success': UK Students and Global Circuits of Higher Education," *Sociology* 43, no. 6 (2009): 1085–1102.

[18] Johanna Waters, "Geographies of International Education: Mobilities and the Reproduction of Social (Dis)advantage," *Geography Compass* 6, no. 3 (2012): 123–136.

[19] Michiel Baas, Imagined Mobility: Migration and Transnationalism among Indian Students in Australia (New York: Anthem Press, 2010); Vanessa L. Fong, Paradise Redefined: Transnational Chinese Students and the Quest for Flexible Citizenship in the Developed World (Stanford: Stanford University Press, 2011); Peidong Yang, "Compromise and complicity in international student mobility: the ethnographic case of Indian medical students at a Chinese university," *Discourse: Studies in the Cultural Politics of Education*, online first (2018): 1–15.

[20] Baas, Imagined Mobility; Shanthi Robertson, *Transnational Student-Migrants and the State: The Education-Migration Nexus* (London: Palgrave Macmillan, 2013).

Transnational Higher Education

The contemporary TNHE sector represents a case of global higher educational landscape undergoing systematic changes stemming from technological multiplication and digitization. It reveals the rapidly shifting ways in which new educational arrangements are built, delinked, reassembled, and experimented with by multiple state and non-state actors. Since the early 1990s, cross-border movements of educational programs and institutions, physically and virtually, have become one of the major transnational flows integral to the internationalization of HE.[21] In addition to intensified cross-border collaborations and partnerships between public and national universities, we also witness an increasing growth of private and non-state sectors venturing into HE provision, thereby contributing to the proliferation of education institutions leading to various foreign degrees and academic credentials. These can take the form of franchised overseas academic programs (including online and distance learning) or degrees, branch campuses, or private institutions modeled after overseas academic models.

In reviewing extant literature on TNHE, there is no fixed definition that scholars and education practitioners can agree on. According to UNESCO, transnational education is broadly defined as education 'in which the learners are located in a country different from that where the awarding institution is based.'[22] But in the context of China, Fang observes that 'an education provision is considered transnational when substantial investment from both foreign and Chinese sides are involved even if the provision does not award foreign degrees.'[23] Tim Mazzarol, Geoffery Soutar, and Michael Seng define TNHE through three overlapping waves of cross-border flows: the first 'involved students travelling to a host nation to study'; the second wave involved the 'alliance or coalition' through twinning programs; and the third wave involved 'the creation of branch campuses in foreign markets and the development of

[21] Futao Huang, "Internationalization of higher education in the developing and emerging countries: A focus on transnational higher education in Asia," *Journal of Studies in International Education* 11, no. 3–4 (2007): 421–432.

[22] UNESCO-CEPES, *Code of Good Practice in the Provision of Transnational Education* (Bucharest: UNESCO/Council of Europe, 2000).

[23] Fang Wenhong, "The development of transnational higher education in China: A comparative study of research universities and teaching universities," *Journal of Studies in International Education* 16, no. 1 (2012): 6.

"on-line" delivery of courses through information and communications technologies (ICT).'[24] This expansive understanding of TNHE as assembled through a network of human, policy, and institutional connections across disparate places is reflected in Huang's definition that takes TNHE as "any cross-border or inter-regional higher education activities or services in a broad sense."[25]

Although proponents have likened the growing TNHE sector to *borderless education*[26] and *borderless university*,[27] others remain wary of such straightforwardly optimistic views. Altbach, for instance, expressed concern that transnational education will deepen inequalities among the global education landscape, whereby the role of world-class universities in Western countries will be strengthened on the one hand, while other ostensibly 'second-tier' universities will continue to have little competitive potential in the globalizing world.[28] Huang's assessment of case studies of TNHE across East and Southeast Asia also revealed the manner in which internationalizing strategies adopted by governments largely maintain an attitude of 'catching up' with the English-speaking world.[29] In her study on Saudi Arabia and Kazakhstan, geographer Natalie Koch argues that the contemporary circulation of Western (European and North American) educational models throughout Asia contributes to shaping a global knowledge economy that largely privileges Western knowledge practices.[30]

The speed and scale at which ICTs are being applied to HE is also believed to have democratized learning through the flexibilization of institutional and curricular structures as well as the widening of participation.

[24] Mazzarol, Soutar, and Seng, "The third wave: Future trends in international education," *The International Journal of Education Management* 17, no. 3 (2003): 90.

[25] Huang, "Internationalization of higher education in the developing and emerging countries," 422.

[26] Stuart Cunningham et al., *The Business of Borderless Education* (Canberra: DETYA, 2000).

[27] Kevin Robins and Frank Webster, *The Virtual University? Knowledge, Markets, and Management* (Oxford: Oxford University Press, 2002).

[28] Philip G. Altbach, "Higher Education and the WTO: Globalization Run Amok," *International Higher Education* 23, (2001): 2–4.

[29] Le-Ha Phan, *Transnational Education Crossing 'Asia' and 'the West': Adjusted desire, transformative mediocrity and neo-colonial disguise* (London: Routledge, 2017); Huang, "Internationalization of higher education in the developing and emerging countries."

[30] Koch, "The shifting geopolitics of higher education: inter/nationalizing elite universities in Kazakhstan, Saudi Arabia and beyond," *Geoforum* 56, (2014): 46–54.

The virtual university, which describes the electronic and online delivering of educational services and activities, is claimed to be the future of HE.[31] One such area that has been heralded as a remedy to educational disparities is the rise of Massive Open Online Courses (MOOCs) such as Coursera, EdX, and Udemy across the 2000s. The president of EdX, Anant Agarwal, goes to the extent to claim that they 'are democratizing and reimagining education by fulfilling [their] nonprofit mission to increase access to high-quality education for everyone, everywhere.'[32] However, evidence gathered has shown that global information flows manifested in the digital divide are highly uneven, including barriers found in individuals' technological capacity and literacy as well as those segmented across class, gender, and race. Schwab correctly noted that inequality is the largest concern associated with the 4IR, especially when innovation and creativity tied to the techno-sciences have tended to benefit the rich while hollowing out opportunities for the poor.[33] Similarly, digital technologies in (transnational) HE may potentially serve the interest of the elite more so than actually closing socio-economic gaps. To this end, Yang accurately cautions that "virtual space is infinite, but it does not promise universality or equality."[34]

Case 1: Indian Students on English-Medium MBBS Courses in China

The Case: Indian Doctors Made in China

With China being the world's largest sending country of international students, its rising profile as a destination for ISM has been largely neglected so far. As of 2016, more than 440,000 foreign students studied in China.[35] Although over half of these foreign students are on non-degree

[31] Parker Rossman, *The Emerging Worldwide Electronic University: Information Age and Higher Education* (Westport: Greenwood Press, 1992).

[32] Anant Agarwal, "MOOCs and the Global Democratization of Higher Education," June 24, 2016, https://evolllution.com/attracting-students/accessibility/moocs-and-the-global-democratization-of-higher-education/.

[33] Schwab, *The Fourth Industrial Revolution*.

[34] Yang, Rui, "Globalisation and higher education development: a critical analysis," *International Review of Education*, 49 no. 3–4 (2003): 281.

[35] PRC State Council, "More Chinese students return from overseas in 2016," March 1, 2017, http://english.gov.cn/state_council/ministries/2017/03/01/content_281475581664446.htm.

courses, since early 2000s mainland Chinese universities have also offered programs catered to foreign students seeking full degree credentials.[36] Among these were English-medium MBBS programs that target specifically international students from developing countries. The number of places on these English-medium MBBS courses increased steadily from 2095 offered by 24 universities in the 2007 admission year to the high watermark of 6020 places offered by 52 institutions in 2013, after which there was a notable decline.[37] In the 2016/2017 admission (the most recent with data available), 45 Chinese institutions offered a total of 3470 places.[38] Students from India most likely make up the largest single-nationality group in these MBBS programs. According to Pallivi Aiyar, Indian students first started heading to China for MBBS in their 'hundreds' since as early as 2004/2005.[39] By 2015, the majority of the 16,694 Indian students in China could be safely assumed to be studying MBBS.[40]

How has this seemingly unlikely project of intra-Asia student mobility come about? Not unlike elsewhere, in India an education in professional fields such as medicine, law, and engineering is integral to many middle-class families' social aspiration and strategy. However, medical education remains highly difficult to access in India, with affordable government-subsidized medical school places reserved for only the most academically competitive students. A significant for-profit private medical education sector has developed in response,[41] but this sector is characterized by very expensive tuition fees. As a result, young doctor-aspirants hailing from the 'the lowest or more struggling sections of India's new middle classes'[42]

[36] Chiharu Kuroda, "The New Sphere of International Student Education in Chinese Higher Education: A Focus on English-Medium Degree Programs," *Journal of Studies in International Education* 18, no. 5 (2014): 445–462.

[37] Medical Council of India, "List of China Colleges," 2015, http://www.mciindia.org/MediaRoom/ListofChinaColleges.aspx (site discontinued).

[38] Ministry of Education China, "List of Institutions and Enrollment Plan for Undergraduate Clinical Medicine Programs Taught in English for International Students, 2016/2017," January 4, 2016, http://www.moe.gov.cn/srcsite/A20/moe_850/201601/t20160120_228496.html.

[39] Aiyar, "Made in China Indian doctors," *The Hindu*, May 17, 2006, http://www.thehindu.com/todays-paper/tp-opinion/made-in-china-indian-doctors/article3134132.ece.

[40] CAFSA, "Statistics for international students in China 2015," April 18, 2016, http://www.cafsa.org.cn/main/research/show-1662.html.

[41] Rita Sood, "Medical education in India," *Medical Teacher* 30, no. 6 (2008): 585–591.

[42] David Sancho, "Escaping India's culture of education: Migration desires among aspiring middle-class young men," *Ethnography* 18, no. 4 (2017): 3.

who are academically as well as financially excluded from medical education at home are compelled to look overseas for alternatives. While previously medical schools located in certain eastern European countries (e.g., Ukraine, Russia, and Armenia) filled this gap, China has more recently emerged as the top player in this segment of the educational market.[43] For example, during the 2011–2014 period, the largest group of candidates taking the Foreign Medical Graduates Exam (or FMGE—a mandatory licensing exam for Indian candidates trained in foreign countries other than the United States, United Kingdom, Canada, Australia, and New Zealand) was those educated in China.[44]

As earlier batches of graduates returned home to attempt the FMGE, however, their low passage rates began to be noticed by the public. In a *Hindustan Times* article titled '80% students flunk mandatory test after MBBS in China, Russia,' Vishav Bharti notes that between 2012 and 2014, the exam pass rate for China-trained candidates was only 18.9%.[45] As rising numbers of apparently under-prepared medical doctor candidates returned, there is now a general realization in India that 'foreign medical degrees are no longer fancy.'[46]

These problematic outcomes dovetail with the first author's (Yang) observations during his ethnographic fieldwork at a provincial university in eastern China (to be referred to as 'CNU' in this chapter) where the international MBBS program was found to have serious quality issues with respect to admission screening, teaching and learning practices, student services, and so on. Yang's research on the Indian medical students in China was conducted between 2014 and 2016, adopting mainly an ethnographic approach. The fieldwork consisted of:

[43] Alya Mishra, "China has become preferred destination for medical education," September 9, 2012, http://www.universityworldnews.com/article.php?story=20120904100946519.

[44] Poulomi Banerjee, "Here's why foreign medical degrees are no longer fancy," *Hindustan Times*, November 23, 2015, http://www.hindustantimes.com/education/here-s-why-foreign-medical-degrees-are-no-longer-fancy/story-HpZtWmiCQFv877cfPqtXZO.html.

[45] Bharti, "80% students flunk mandatory test after MBBS in China, Russia," *Hindustan Times*, 2015, http://www.hindustantimes.com/punjab/80-students-flunk-mandatory-test-after-mbbs-in-china-russia/story-MkWKHKKMdzihRNd2gRMKUN.html.

[46] Banerjee, "Here's why foreign medical degrees are no longer fancy."

1. a week-long ethnographic observation and interaction with Indian MBBS students at CNU campus in March 2014;
2. a two-week trip to four Indian students' hometowns in the state of Tamil Nadu during June–July 2014;
3. a week-long visit to Kolkata and Bengaluru in early 2016 focusing on an India-based educational intermediary.

These intense ethnographic trips were further supplemented by Yang's continuous engagement with Indian student informants through social media.

Pragmatism, Compromise, and Mediocrity: Realities of International Educational Mobility

The case of Indian MBBS students in China materialized primarily as an outcome of the pragmatism of both the educational consumers and educational providers in attempting to achieve their respective objectives. For the Indian students, the objective is simply to obtain an MBBS degree at an affordable cost. For the Chinese universities, especially lower tier ones like CNU, it is to reap financial as well as prestige gains from having international students that they are otherwise not in a position to attract. As Yang's fieldwork revealed, however, the Indian students subsequently found the Chinese MBBS program falling short of their expectations, sometimes in significant and unsettling ways. Even so, they were generally willing to accept and acquiesce because this represented for them a 'second chance' that they must settle for. In other words, studying MBBS in China was a compromise that most Indian students have willingly made. Similarly, the Chinese institution also found its initial objective of achieving financial and reputational gains at least partially defeated, because not only did quite a number of Indian students struggle to pay tuition fee installments on time upon enrolling in China, their general lack of cultural capital (e.g., in areas of English proficiency, cosmopolitan outlook and competence, and academic ability) also added little prestige to CNU in the eyes of the university.

The Indian students' desires for an MBBS degree from China are primarily shaped locally in their home-country context as a tenuous strategy for achieving social mobility through education. Yang's informants—both the Indian students and their parents in the study—typically had very little prior knowledge about China and Chinese higher education institutes

(HEIs), and did not in any significant way cite the imagined qualities of the host country and institution as reasons for their pursuit of this educational mobility. In fact, the only 'pull' factor consisted in the significantly lower tuition fees at the Chinese medical schools—equivalent to about a quarter to a third of what it costs in a private medical school in India. This finding contrasts notably with a few other accounts about international students in which active 'imaginative work' about the culture of the destination country/society and the features of its education system(s) featured prominently in students' narratives about studying abroad.[47] This contrast shows that the socio-cultural construction of educational desires can be highly contingent contextually. While education has been theorized as a form of cultural capital that must be simultaneously *institutionalized* (as credentials/diplomas) and *embodied*,[48] depending on context, social actors may emphasize predominantly only one aspect while bracketing the other. This seems to be the case with the Indian MBBS students in China, who primarily regard studying in China a second chance to obtain a credential that they are excluded from domestically; they seem to pay scant attention to the embodied as well as experiential aspects of their education in China.

Due to this local/domestic constructedness and orientation of the Indian students' rationality for pursuing MBBS in China, mobility in this case largely fails to act as a catalyst for value-added education. Educational mobility has often been touted for creating additional values to the multiplicity of actors involved in it, be it the countries, regions, cities, institutions, and most importantly, the people.[49] For learners, especially, educational mobility is believed to be the key in enhancing one's cultural capital through opening access to advanced knowledge, inter-/cross-cultural competencies, cosmopolitan perspectives, and so on. However, for the majority of the Indian MBBS students in Yang's study, few of these would seem true (although there inevitably are exceptions to the rule, which cannot be discussed here due to limit of space). As a telling example, most Indian MBBS students at CNU regarded learning the Chinese

[47] Suzanne E. Beech, "Why place matters: imaginative geography and international student mobility," *Area* 46, no. 2 (2014): 170–177; Fong, *Paradise Redefined*.

[48] Bourdieu, "The Forms of Capital."

[49] Francis L. Collins and Ho Kong Chong, "Globalising higher education and cities in Asia and the Pacific," *Asia Pacific Viewpoint* 55, no. 2 (2014): 127–131.; Francis L. Collins et al., "Mobility and desire: international students and Asian regionalism in aspirational Singapore," *Discourse: Studies in the Cultural Politics of Education* 35, no. 5 (2014): 661–676.

language as extremely difficult and a burden. Language barriers, together with racially and socio-economically based prejudices and discriminations, led to the isolation of the Indian students in their host institution, as well as their general lack of interaction with the host society. Furthermore, in order to satisfy the learning needs of the Indian students, it is common for the Chinese universities to employ Indian-background lecturers to teach on the program. When Chinese lecturers taught according to their own China-based medical curriculum or syllabus, students typically reacted adversely instead of appreciating it as curricular diversity, citing the pragmatic consideration that the Chinese syllabus does not help them toward passing the India-based FMGE. In a similar vein, due to language and cultural barriers, Indian students are unable to benefit optimally from medical practicums conducted at hospitals in China.

These and various other observations reveal a palpable gap between the oft-claimed benefits of international educational mobility on the one hand and the realities as found in the experiences of the Indian MBBS students in China on the other. This case seems to show that, for academically and socio-economically not-so-privileged students pursuing educational mobility in non-elite institutions, a production of educational mediocrity[50] may be a possible outcome.

Case 2: Singaporean Students in Private Transnational Degree Providers

The Case of TNHE in Singapore's Private Institutes

Transnationalization of HE driven by economic globalization gained momentum in the 1990s as part of the government's aim to transform Singapore into a global education hub.[51] The government's search for 'global city' status through HE began in 1998 with the launch of the World Class Universities project to transform Singapore into 'Boston of the East'. A key strategy involved courting renowned American universities such as Wharton, MIT, Cornell, and Duke among others to establish satellite campuses and joint ventures in Singapore. The Global Schoolhouse initiative was introduced in 2002 as an explicit strategy to nurture HE as a service

[50] Le-Ha Phan, Transnational Education Crossing 'Asia' and 'the West.'

[51] Ravinder Sidhu, Kong Chong Ho, and Brenda S.A. Yeoh, "Emerging education hubs: the case of Singapore," *Higher Education* 61, no. 1 (2011): 23–40.

sector for revenue growth vis-à-vis the fashioning of a 'virtuous circle,' whereby universities—especially research-intensive flagship institutes such as the National University of Singapore and the Nanyang Technological University—are perceived to generate talented citizens who would then create knowledge capital and networks that drive knowledge-based economy.[52] In addition to transforming the domestic public-autonomous universities into global flagship centers of research and innovation excellence through various international partnership projects (such as Yale-NUS College of liberal arts and sciences, Duke-NUS medical school, and NTU-Stanford), the Global Schoolhouse initiative also encouraged the privatization of HE by attracting new players into the educational market.[53]

Private institutes in Singapore (and many parts of East and Southeast Asia) are not granted with degree-awarding powers but instead partner with overseas universities to offer programs that would lead to the conferment of a degree by the overseas 'home' university. The programs on offer include both part-time and full-time degree courses spanning across social sciences to business and marketing, offering a wide array of overseas credentials from reputable partner universities, such as University of London from the United Kingdom, University of Buffalo from the United States, and RMIT from Australia. These home universities also take advantage of these partnerships as part of their internationalizing strategies to grow their presence across the world and to capture a portion of the revenue afforded by this emerging transnational education industry. In forging these cross-border institutional linkages that facilitate networked circulation of educational models, knowledges, and policies, private HEIs serve as important individual sites in the global assemblage of Singapore's education hub formation.[54] Much of this assemblage clearly thrives on the condition afforded by revolutionized technology, which has made possible new modes of collaboration, organization, and service provision in compressed time-space that is the current (neoliberal) imaginary.

The rapid expansion of a transnational private HE sector converged with the city-state's response to the increased tertiary participation rate produced by the mid-1980s school-leavers from the 'youth bulge' generation. This is

[52] Kris Olds, "Global Assemblage: Singapore, Foreign Universities, and the Construction of a 'Global Education Hub'," *World Development* 35, no. 6 (2007): 973.

[53] Peter Waring, "Singapore's global schoolhouse strategy: retreat or recalibration?," *Studies in Higher Education* 39, no. 5 (2013): 874–884.

[54] Olds, "Global Assemblage."

compounded by a rising middle-class aspiration for higher qualifications and the continued impact of credential creep (i.e., the simultaneous inflation of minimum credentials required for a given job and devaluation of diplomas/degrees). Due to recent public concerns about the lack of local university places for Singaporeans to pursue their degree education, the government convened a committee in 2012 to explore strategies for expanding the HE landscape culminating in a report for creating multiple university pathways. Private HE sector was construed in this report as having a 'role in *complementing* the public university sector, by injecting greater course diversity and supporting workforce development (emphasis added).'[55] Private HE was therefore framed within state policy discourse as demand-absorbing, providing opportunities to those who needed to upgrade workforce skills and knowledge, and expanding the educational service market.

According to the Council of Private Education, more than 100,000 Singaporeans pursue degree and diploma studies across approximately 71 private education institutes in Singapore. By 2012, there was already an estimated 47,500 Singaporeans enrolled in full-time and part-time undergraduate degree programs in the city's four largest private institutes. The majority are fresh A-level and diploma graduates who were unable (or did not try) to secure places in the more established and reputable public-autonomous flagship universities—namely the National University of Singapore, the Nanyang Technological University, and the Singapore Management University. Another group consists of young working adults in their 30s who wish to upgrade their existing credentials through 'top-up' degree programs. Together, this sizeable student population has grown to match the number of Singaporeans enrolled into the local public universities, which was estimated to be just over 45,000 in the same year.

Transnational Higher Education: Democratized and Borderless?

The idea that private transnational education is a 'second chance' option to obtaining a degree began to emerge during the second author's (Cheng) ethnographic fieldwork conducted between 2012 and 2014. During this period, Cheng interacted with numerous domestic students in private HE,

[55] Ministry of Education Singapore, "Final Report of the Committee on University Education Pathways Beyond 2015," August 28, 2012, https://www.moe.gov.sg/docs/default-source/document/ceup/2012/08/cuep-report-greater-diversity-more-opportunities.pdf (site discontinued).

out of which 35 interviews were held individually and in focus groups. Students spoke about private degree education as an alternative pathway to that of mainstream flagship universities, without which they would need to consider the more expensive route of pursuing a degree overseas. As such, the availability of overseas degree programs locally becomes a palpable option given they are more financially viable than living and studying abroad. While this dominant narrative reflects a form of students' practical reasoning, it is informed by private institutes' marketing discourses that employ the very same rhetoric of private degree education as offering young people a 'second go' at university education. Surveying various private institutes' websites revealed this language built into graduate and student 'testimonials' selected to promote their degree programs. In doing so, private education institutes participate in the appropriation and marketization of young people's aspirations, wherein students are framed as consumers and whose educational desires are increasingly co-opted into commercial agendas.[56] As such, the 'second chance' discourse that helps frame local understandings of private degree education[57] echoes more broadly held beliefs that TNHE offers the possibility of making university education borderless, contributing to widening participation, and by extension represent a more democratized moment of education and learning.

The vocabularies of *borderless* and *democratization*, however, serve to mask more complex and nuanced details of how disadvantage and hierarchies are produced through TNHE, even as it paves an additional route for credential-seeking youths. The analytic prism therefore needs to pay heed to how the 'actually existing' experiences of transnational education is constituted through reproduction of power relations and value hierarchies. As Waters and Leung argue based on their work on TNHE in Hong Kong, there is very little critical analysis on its complex spatialities—'how it can be conceivably both detached from the local education system and yet also at the same time profoundly implicated in localized processes of social reproduction.'[58]

[56] Rajani Naidoo, Avi Shankar, and Ekant Veer, "The consumerist turn in higher education: Policy aspirations and outcomes," *Journal of Marketing Management* 27, no. 11–12 (2011): 1142–1162.

[57] Yi En Cheng, "Commentary: Is private higher education in Singapore a 'second chance' option?," September 17, 2017. http://www.channelnewsasia.com/news/singapore/commentary-is-private-higher-education-in-singapore-a-second-9215636.

[58] Johanna Waters and Maggi W. H. Leung, "Domesticating transnational education: discourses of social value, self-worth and the institutionalisation of failure in 'meritocratic' Hong Kong," *Transactions of the Institute of British Geographers*, 42, no. 2 (2016): 235.

Educational hierarchy in Singapore has long privileged 'Western' overseas universities, as reflected in the government's practice of sending the 'brightest' students abroad for university education in the Global North under prestigious scholarship schemes, followed by a more localized competition among the public universities.[59] Private TNHE institutes, as the new kid on the block without the established resources and reputation relative to the domestic universities, are categorically pushed to the bottom rung of this hierarchy. Domestic students enrolled into private institutes are structurally constituted as 'educated non-elites' in the state's vision of Singapore as an epicenter of knowledge and talent.[60] Even though many of them are considered relatively privileged enough to be able to pursue university education, as opposed to the least advantaged youths in vocational and technical institutes[61] or those who have no financial means to pursue HE, private degree students often face uncertainty in job prospects and do not have access to a wide variety of employment opportunities unlike their counterparts studying in domestic public-autonomous universities. This is largely due to the lack of faith in TNHE programs and degree credentials by employers and hirers that can be attributed to multiple factors, including stereotypical views about the quality of students and programs. Currently, 42% of graduates of private TNHE were unable to secure full-time jobs within six months of completing their studies, which is a striking contrast to an 83% successful full-time job rate among the public university students.[62] Two key points about the challenges faced by private TNHE students in Singapore can be made that connect to localized social reproduction.

First, even though Western overseas universities and their credentials are much sought after by employers in Singapore, they do not remain as such in the context of private TNHE. Instead, private TNHE-awarded degrees undergo a process of value erosion as they cross geographical boundaries

[59] Rebecca Ye and Erik Nylander, "The transnational track: state sponsorship and Singapore's Oxbridge elite," *British Journal of Sociology of Education* 36, no. 1 (2015): 11–33.

[60] Yi En Cheng, "Educated non-elites' pathways to cosmopolitanism: the case of private degree students in Singapore," *Social & Cultural Geography* 19, no. 2 (2018): 151–170. https://doi.org/10.1080/14649365.2016.1266026.

[61] Terence Chong, "Vocational education in Singapore: meritocracy and hidden narratives," *Discourse: Studies in the Cultural Politics of Education* 35, no. 5 (2014): 637–648.

[62] Sandra Davie, "Private school graduates find it harder to land jobs: Poll," *The Straits Times*, September 24, 2016, http://www.straitstimes.com/singapore/education/private-school-grads-find-it-harder-to-land-jobs-poll.

and get reinterpreted in the local context of existing HE hierarchies vis-à-vis a politics of value recognition tied to student worth and institutional reputation. This cross-border erosion of (Western) credential value poses a challenge to the notion of TNHE as a form of borderless education that can uproot itself from geographically embedded forces.

The second point relates to how TNHE has been postulated to have democratizing impact on participation in HE. The case of Singapore has indeed demonstrated the possibility of widening university participation for a broader range of young people, and which serves as a discourse that appeals to the popular imagination, including the students' own perceptions of private TNHE. Nevertheless, it is also revealed through research that more complex intricacies of power relations operating within private institutes continue to reproduce (dis)advantage. For instance, even within a single institute some university programs are perceived as better than others. Generally, American degree programs are perceived by students as of a higher class than the Australian counterparts. But those who wish to enroll into the American programs would have to pay a higher tuition fee as compared to Australian universities. In terms of access to opportunities to partake in overseas study and work placements that might support future employability, there is also evidence that some working-class students could not afford to pay for additional expenses needed to enter such programs. As such, while TNHE offers the possibility of international education experience with respect to their foreign curricular programs, not every student has equal access to tangible forms of international learning experiences and especially for socio-economically constrained individuals. These exclusions on the ground serve as a caution to viewing TNHE as any more democratic than earlier forms of educational arrangements.

Discussion and Conclusion

While we could have offered a discussion of how HE may be impacted by and can in turn respond to 4IR from a functionalist angle, evidently this is *not* the approach we have taken in this chapter. Instead, leveraging on our respective studies in emerging student mobilities and transnational private HE in Asia, we have attempted to reflect indirectly on claims tied to 4IR as a technologically enabled and driven force that would disrupt HE learning and training. In the process, we have pondered the roles of student mobility, transnationalization, economic/social/cultural capitals, social reproduction—and the complex cross-border interplay of these factors—in animating today's global landscape of HE.

Transnational mobilities and connectivities in HE have no doubt become deeper and more extensive as the result of the 3IR-driven globalization of the preceding era. With the onset of the 4IR, these processes are likely to further accelerate and intensify. This notwithstanding, our research suggests that the patterns of educational mobilities and transnational linkages are highly uneven, and remain powerfully shaped by hegemonic global structures and hierarchies around knowledge authority, institutional prestige, and country reputations. Our findings show that today's HE institutions adopt 'globalization' or 'internationalization'—often in ways that reflect dominant technofetishized impulses—as strategies to boost student enrollment, whereas students often use their participation in educational mobilities and transnationalism as alternative routes to overcome *locally* based barriers to access educational pathways and labor markets. Thus, we contend that, while examining the globalizing aspects of HE and participation that are often associated with globalization and are projected to intensify in the age of 4IR, we must not lose sight of the locally embedded logics and rationales underpinning institutions' and individuals' articulations and experiences of HE.

More broadly, with the critical and culturalist analytical perspective we adopt, our hope through this chapter is to open up a more critical conversation about the current state and future direction of scholarship on 4IR and HE. Existing discourses on 4IR remain very much dominated by the elite industrial and academic voices that coined the concept in the first place.[63] Characterized by a strong technocratic/technophilic impulse and futuristic orientation, such discourses address primarily the policymakers and the elites, but elide the 'on the ground' experiences and subjectivities of the more disadvantaged and marginalized. Hence, for instance, in the WEF's recent report *The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution*, there are many a prediction and pronouncement about the 'hot' skills of the future, which all seem to us to be largely out of touch with the ways in which socio-culturally and geographically embedded actors are engaging with HE as means of realizing locally defined social aspirations and desires.[64] In a sense, our chapter aspires to be a corrective to prevailing 4IR discourses which fail to

[63] Schwab, The First Industrial Revolution.

[64] World Economic Forum, "The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution," January 2016, http://www3.weforum.org/docs/WEF_Future_of_Jobs.pdf.

challenge the continued hegemony of the business world and capitalist economy impacting upon HE alongside the unevenness, hierarchies, and inequalities that are reproduced in the process. We argue that paying attention to these issues is crucial if we wish to take seriously and critically the complex relationships between 4IR and higher education.

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CHAPTER 4

Academic Library Futures in a Diversified University System

Lorcan Dempsey and Constance Malpas

Universities (and Libraries) in Transition

Following World War II, the higher education sector grew rapidly. The increases in college attendance were dramatic. For example, in 1949, 2.4 million students attended US colleges and universities; by 1969, total enrollment had grown to 8 million students; and by 1994, enrollment had risen to 14.3 million students. And this growth continues. Between 2004 and 2014, enrollment increased 17%, from 17.3 million to 20.2 million.[1] As the higher education sector has grown, the number of US academic libraries has increased as well, growing by 6% from 2002 to 2012, and totaling more than 4000 in 2015.[2]

[1] Thomas D. Snyder, Cristobal de Brey, and Sally A. Dillow, *Digest of Education Statistics 2015* (Washington D.C: National Center for Education Statistics, 2016), 460.
[2] Snyder, Brey, and Dillow, Digest of Education Statistics 2015, 881.

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Higher education is now the subject of an intense debate about mission, organization and direction. This is driven by multiple factors, including affordability and inclusion, research evaluation and the associated influence of rankings and increased recognition of the diversification of mission. An important strand in the United States has been the discussion about institutional isomorphism, which has featured centrally in influential recent contributions.[3] Institutional isomorphism refers to the tendency of institutions in a field to come to resemble each other over time, shaped by coercive (mandated) or normative (professional) influences. In the higher education field, Michael Crow and William Dabars have coined the terms *Harvardization* or *Berkeley envy* for a historical trend they observe: universities have aspired to those institutions as common models of excellence.[4] They, and others, argue that the needs of their constituencies demand a more plural form of education, where different types of institution fit different niches.

And, indeed, it has become increasingly clear that universities are sorting themselves into new patterns of development. For example, Crow's own institution, Arizona State University, is very deliberately charting a course as a new type of mega-university, arguing that it is possible to increase simultaneously both inclusiveness and research excellence. Other patterns are apparent: the residential liberal arts college, for example, which is developing career-oriented professional online offerings (e.g., Indiana Wesleyan University), the regional public university seeking to streamline based on a distinctive career focus (e.g., the University of Texas Rio Grande Valley), the system with shared services (e.g., University of Georgia) and so on. As universities change and grow, so do libraries, and there has also been much discussion of the future of academic libraries.[5]

[3] Paul DiMaggio and Walter W. Powell, "The Iron Cage Revisited: Collective Rationality and Institutional Isomorphism in Organizational Fields," *American Sociological Review* 48, no. 2 (1983): 147–160; Kevin Carey, *The End of College: Creating the Future of Learning and the University of Everywhere* (New York: Riverhead Books, 2015); Michael M. Crow and William B. Dabars, *Designing the New American University* (Baltimore: Johns Hopkins University Press, 2015), 118.

[4] Crow and Dabars, Designing the New American University.

[5] For recent examples consider Steven Bell, Lorcan Dempsey, and Barbara Fister, *New Roles for the Road Ahead: Essays Commissioned for ACRL's 75th Anniversary* (Chicago: Association of College and Research Libraries, 2015); Stephen Pinfield, Andrew M. Cox, and Sophie Rutter, *Mapping the Future of Academic Libraries: A Report for SCONUL* (London: SCONUL, 2017). https://sconul.ac.uk/sites/default/files/documents/SCONUL%20Report%20Mapping%20the%20Future%20of%20Academic%20Libraries.pdf.

Against the university background sketched above, such discussion shares two interesting features.[6] First, it often proceeds without reference to the universities of which libraries are a part. We contend that the most important long-term influence on the library is the requirement placed on it by changing patterns of research and learning. These changing patterns, in turn, are shaped by the focus of the parent university or college and the directions it is taking. And, as we noted above, a variety of patterns is emerging here. Second, it often presumes some homogeneity of approach or direction, different only in degree among libraries. This presumption of homogeneity encourages a view of academic libraries in which the research library is seen as a terminal point in evolution, rather than as one type among others. However, where universities and colleges seek to differentiate themselves this presumption is increasingly misleading. The models of excellence for libraries supporting, say, an elite comprehensive research university, a liberal arts college devoted to broad-based student learning, or an increasingly career-oriented public institution will be very different from each other.

These factors mean that despite considerable exploration, discussion of library futures can be somewhat partial. We contend that different types of academic libraries will be on different vectors, influenced by the types of universities or colleges they support. In the remainder of this chapter, we will consider the future of academic libraries in the context of a diversifying higher education system. We will proceed as follows. We will consider how the academic library developed in parallel with the growth of the higher education system more broadly. We then will look at some general library trends brought about by the digital shift. We will go on to consider how libraries in different types of higher education institutions will likely develop different emphases to support the specific directions of their host institution. To facilitate this discussion, we propose a simple typology of higher education institutions. This is based on some collaborative work we currently are engaged in to characterize libraries in the context of university strategic directions (in a later stage of this work, we will be looking at developing a more refined view of the library service portfolio supporting different types of university. This is based on field work currently in process).[7]

[6] Unless stated otherwise, when we use library in this unqualified sense we mean academic libraries.

[7] The University Futures, Library Futures project is a collaborative initiative of OCLC Research and Ithaka S+R, with support from the Andrew W. Mellon Foundation. See "University Futures, Library Futures," OCLC, last updated May 31, 2017, https://www.oclc.org/research/themes/systemwide-library/library-futures.html.

Most of our examples are drawn from the United States, which has an enormously rich and diverse ecosystem of educational provision. Of course, in many other countries there may be a more systemwide approach, guided by public policy and national planning or funding (and this certainly carries over into library provision, where nationally supported shared infrastructures, union catalogs for example, or shared content licensing arrangements, are common). However, we believe that similar trends are observable elsewhere, and that libraries worldwide are on similar trajectories even if they are realized unevenly.

The Collections-Based View of the Library

The enormous growth in higher education in the post-war period was mirrored by a growth in publication, and of the libraries that managed those publications for universities and colleges. Consider journal publications.[8] This is the period of De Solla Price's big science, where government funding of big science and technology challenges coincided with the professionalization of research, the emergence of commercial scholarly publishers and "the growing importance of published works as career-defining tokens of prestige for academics."[9] The academy outsourced reputation management to the publishing system, and at the same time that publishing system was increasingly commercialized. This has led to strenuous discussions about models of open access, funder and national policy attention to the dissemination of research outputs and occasional suggestions that management of the scholarly record be repatriated to the academic community.

On the monograph side, the volume of both consumer and scholarly book publications saw big increases. In 1945, there were a total of 6548 book titles published in the United States. By 1965, the number rose to 28,595 books published. By 1985, the number rose to 50,070 titles.[10] By

[8] Michael Mabe, "The Growth and Number of Journals," *Serials* 16, no. 2 (2003): 191–198.

[9] Aileen Fyfe, Kelly Coate, Stephen Curry, Stuart Lawson, Noah Moxham, and Camilla Mørk Røstvik, "Untangling Academic Publishing: A History of the Relationship Between Commercial Interests, Academic Prestige and the Circulation of Research," *Zenodo*, May 25, 2017, https://zenodo.org/record/546100#.Wldw-a6nHRY.

[10] Jean Peters, "Book Industry Statistics from the RR Bowker Company," *Publishing Research Quarterly* 8, no. 3 (1992): 12–23.

the 1970s, these factors had established the traditional collections-based view of the library in the print world. The library was associated strongly with the collection of print materials. A 'good' library was a 'big' library, because it assembled locally a large part of the scholarly and cultural record for prospecting by students and researchers.

Three overlapping central features are worth noting here: *identity*, *value* and *workflow*. The identity of the library was formed by its print incarnation: a central building which makes print collections available. Powerful associations grew up around this: the library at the heart of the university, a physical manifestation of the cumulating scholarly and cultural record, which is created through research and scholarship, shared through teaching and learning, and preserved by the library. These associations are still strong. Indeed, it often is difficult to separate the idea of the library as a 'building' from the idea of the library as a 'service.' Consider media stories about academic libraries: they often will be accompanied by stock images of the Long Room at Trinity College Dublin, or a similar wood-paneled, book-lined library interior.

In parallel, the value of the library was associated strongly with access to the assembled print record, to its organization and to its provision of adjacent study spaces. Until recently, the collections model of libraries has meant that academic libraries have measured their quality or value in terms of how big their collections are—every library trying to be as much like Harvard as possible. In this way, we have had a fairly monolithic model of what constitutes excellence, often focused on collection size, circulation and gate counts, and library expenditures. A university that provided more educational and research materials could offer more comprehensive programs and attract more students. This model of excellence continues to be perpetuated in library rankings and national statistical reporting, which emphasize 'counts' of items (or titles) in the collection, or the size of the library budget relative to other core institutional expenditures.

This centrality is reenforced by workflow. Resources are scarce in a print world, and the library improved student and researcher access by assembling material locally. In a print world, researchers and students built much of their workflow around the collections: you had to work with those materials to get your work done. The library was very much a part of the fabric of research and learning behaviors, because print materials were central to those behaviors. In this way, this model of the library became deeply embedded in behaviors and expectations.

A Trend Toward Services and Engagement

However, as the digital shift took hold in the 1970s and later, the print collection gradually became less central to research and learning behaviors (although, of course print collections remain important). At the same time, the deep embeddedness of the library in perceptions, values and workflows has meant that change has not been simple, linear or free of tension. One can point to three summary trends as the digital/network shift emerged. Here, again, it is important to note that it is changes in learning and research behaviors that are the major driver for the library. The library serves the institutions of which it is a part; it does not stand alone.

Reconfiguration of the Information Space by the Network/Digital Environment

If resources were scarce in the print world, they are certainly now abundant. We have seen an extraordinary growth and diversification of resources in the network environment which support the discovery, creation and use of information resources (see Fig. 4.1).

The network is rich in resources which help create, curate and share information resources. The library collection is potentially an important component, but one component only, of an array of resources and services available to researchers, teachers and learners. This creates an interesting shift for the library. Increasingly, the library facilitates access to external network resources alongside access to its owned or licensed collections. The great growth in use of resource guides is symptomatic of this shift, as are such measures as proxying access to Google Scholar, adding metadata for freely available e-books to the catalog and so on.

Reconfiguration of Research and Learning Work by the Network/Digital Environment

While practices vary enormously across individuals, institutions and departments, there have been major changes in how research and learning get done in a network environment. A full discussion of this complex topic is not warranted here, but it is apt to note some issues in relation to the creation and use of information resources.

The first issue relates to the process and product. In the print model, the products of research and learning were fixed publications—articles or

Fig. 4.1 Examples of online information resources

books—produced when the work had been completed. The actual process of research was not visible, nor were intermediate outcomes such as research data, software or methods. Now, in a digital, network environment these intermediate outcomes may be visible and sharable. Moreover, there are arguments, and in some cases mandates, for making these outcomes more readily available in the interests of reproducibility, efficiency, reputation and so on. Similarly, learning materials are potentially of more general interest, and the production of open educational resources is gaining momentum.

In this context, there is a growing role for the library in assisting with the creation and use of institutionally produced materials, or as David Lewis puts it: "… supporting knowledge creation and the curation and preservation of local content."[11] Such local content may include research data, researcher profiles, open educational resources, theses and disserta-

[11] David W. Lewis, *Reimagining the Academic Library* (Lanham: Rowman & Littlefield Publishers, 2016), 145.

tions, workflows, digitized special materials, locally produced video and so on. The curation and disclosure of these resources is a growing interest of libraries and universities, but researchers also have other venues where they share their outputs. These include discipline- or format-specific venues (e.g., Arxiv, the Biologic Specimen, Data Repository and myexperiments.org). General tools may also be used (e.g., GitHub for data and software). The rise of ResearchGate has been interesting in this context. In some countries there is national support for such curation or sharing (e.g., DANS and ANDS in The Netherlands and Australia respectively). And of course, there are now many national or funder imperatives to share these resources.

The second issue is the emergence of research workflow support. This means that workflow support becomes more important as the work of research and learning is enacted in this digital environment. Research and learning behaviors are shaped by, and in turn shape, evolving workflow support services. Workflow, one might say, is the new content. Some examples include

1. curation and sharing of research artifacts: A range of tools and services was discussed in the last section. There are institutional, disciplinary, commercial and publicly supported approaches across a broad range of requirements here, looking at the creation, management, sharing and discovery of resources. These include reference management services, discovery tools, lab notebooks, research networking services, preprint servers, data management services and so on. These are being created by specialist providers, by publishers, by research groups and by many others;
2. research process support: These provide 'prefabricated' workflow support, articulating tools around particular processes. Examples here are laboratory information systems, electronic lab notebooks and scientific workflow systems (e.g., Taverna). And at the same time, researchers assemble their own workflow from many tools—collaborative working and document sharing for instance, or data analysis and visualization approaches.

The emergence of learning and teaching workflow support is a third issue of note. Learning management systems and e-portfolios are now routine, as are various forms of participation environments. Much learning and teaching activity is mediated through a systems environment.

The blurring of identity, outputs and workflow is also an issue to consider. For many researchers there is increasingly a blurring of content, workflow and network identity as they disclose and share publications and experience in Google Scholar, ResearchGate or other networks as part of ongoing work. At the same time, their institutions similarly are curating and disclosing profiles through VIVO, research information management systems (e.g., Elsevier Pure or Symplectic Elements) and so on. A culture of evaluation and rankings encourages more attention to reputation management at various levels across the academic enterprise.

Another issue to take note of is the use of 'social machines.' We are now very familiar with webscale interaction around network platforms—Facebook, eBay and so on. Such 'social machines'[12] (Tim Berners-Lee's phrase) are central to many research and learning behaviors. Twitter, GitHub and Wikipedia are obvious examples. However, there are also research-specific resources emerging (e.g., Zooniverse). Many of the resources already mentioned in this section mobilize network communities at scale. In an interesting short article about the future of scholarly communication, David de Roure writes: "Scholarship itself is becoming an in-the-wild experiment in the co-production of social machines."[13] Researchers may participate in many communities of interest.

The final issue concerns collaboration. Research is increasingly team-based and cross-institutional. International collaboration is also growing. The percentage of all scientific papers that were internationally coauthored more than doubled in the 20 years after 1990.[14] This has made it common for researchers to use a variety of collaboration tools and environments to help get their work done.

Again, this creates an important shift for the library. The library can no longer expect learners and researchers to build their workflow around the library, as they did to some extent in a print world. Increasingly, the library has to think about how to make its services and resources available in ways which can be integrated with user behaviors. Putting curated library resources in the learning management system comes to mind. At the same time, the range of services provided by the library is growing, as the library

[12] Tim Berners-Lee, and Mark Fischetti, *Weaving the Web: The Original Design and Ultimate Destiny of the World Wide Web by its Inventor* (Harper: San Francisco, 1999).

[13] De Roure, "The future of scholarly communications," *Insights* 27, no. 3 (2014): 237.

[14] Caroline S. Wagner, Han Woo Park, and Loet Leydesdorff, "The continuing growth of global cooperation networks in research: A conundrum for national governments," *PLoS One* 10, no. 7 (2015): e0131816.

looks at research and learning workflow support (e.g., research data management), and at a mix of awareness, education and operational support. Libraries are often now providing advice and services around copyright management, citation management, faculty profiles and general reputation management, data management, digital scholarship, creation of open educational resources and so on.

For research libraries especially, this leads to an important distinction, which will cause libraries to think differently about how they organize and direct attention to support research. This is a distinction between outside-in resources and inside-out resources.[15] The dominant library model of collections has been an outside-in one, where the library is buying or licensing materials from external providers and making them accessible to a local audience. This is an important role and will continue.

In the inside-out model, the university and the library support resources which may be unique to an institution, and the audience is both local and external. The institution's unique intellectual products include archives and special collections, or newly generated research and learning materials (e.g., e-prints, research data, courseware, digital scholarly resources etc.), or such things as expertise or researcher profiles. Often, the goal is to share these materials with potential users outside the institution.

Reconfiguration of Library Cooperation by the Network/Digital Environment

Library cooperation has always been very important. Across the world, libraries collaborate in consortia or within publicly provisioned structures. For example, groups of libraries share the burden of cataloging, have built union catalogs and lend materials to each other through requesting networks. Such collaboration is now extending to the building of shared infrastructure for the management and preservation of digital materials. The network environment makes such collaboration easier to achieve, and shared infrastructure, collections and other capacities will become more common. Eight universities in Hong Kong are collaborating to deploy a single shared library management system, a pattern that is increasingly common. The academic libraries of Ontario have a shared discovery envi-

[15] Lorcan Dempsey, "Library Collections in the Life of the User: Two Directions," *Liber Quarterly* 26, no. 4 (2016): 338–359.

ronment providing access to their collections, as well as other shared infrastructure and services, again a pattern that is increasingly common. Indeed, groups of libraries are looking at how to streamline the whole discovery to delivery logistics apparatus so as to give their users access to the groups' collections as easily as to their own local libraries.

A particularly interesting development here, aligned with our previous comments about collections, is the evolving trend toward moving print collections into shared management arrangements. Given the changes in research and learning behaviors described above, given the pressure on space in many campuses, and given the desire to develop more social space, many libraries are exploring how to manage down their print collections, and in some cases to move them into shared management environments. Several new consortia have been formed around this interest and it has become a central task for others. At the same time, there is considerable interest in building shared facilities for print storage, alongside institutional off-site provision. In fact, in coming years, we can expect to see a large part of the aggregate print resource managed in shared facilities. This has led to discussions of the 'collective collection,' where there is a recognition that there is benefit in shared attention to and management of the aggregate print collection.[16]

What we are seeing, in fact, is a move away from configuring library buildings around collections and toward configuring them around user experiences (e.g., collaborative working, access to specialist materials or expertise and exhibitions). And, indeed, there is something of a renaissance in the construction of new library buildings configured in this way.

Some General Library Trends

Against this background, we briefly discuss some general library trends. It is interesting to think about what has changed as the library has evolved over the last 25 or so years. The collections-based library still needs to be supported, and the requirements of the services-based or workflows-based library are additive (see Table 4.1).

[16] Lorcan Dempsey et al., Understanding the collective collection: towards a system-wide perspective on library print collections (Dublin: OCLC, 2013).

Table 4.1 Changing functions of the library

Term	*Collections-based library*	*Services-based library*
Library	Defined by library operation metrics (collection, reference)	Defined by university needs (research support, student success and community engagement)
Organization	Bureaucracy: reproduction of their system of means is their main organizational goal	Enterprise: goals, and the change of goals, shape and endlessly reshape the structure of means
Expertise	Subject, process	Partner in research and learning, creation etc.
Systems	Back office	Workflow, digital scholarship and shared systems
Space	Configured around collections	Configured around user experiences
Collections	Just in case, central, institutional, consumption	Facilitated (just in time), one service among others, collective and creation

Library

We have described a shift in emphasis above, from a library built around its collection to one which must think about engagement with research and learning needs in a de-centered network environment. This leads to an important refocusing of how goals are defined. In the print-based library, where purpose and practices were well understood, goals tended to be defined in terms of the library itself, its collections and services. However, the library now increasingly defines itself in terms of university needs in a changing environment—how to make research more productive, how to contribute to student success and retention, how to improve the engagement between the university and its community and so on.

Organization

Manuel Castells distinguishes between bureaucracies and enterprises.[17] The stable and well-understood goals of the print-based library favored a focus on managing and improving the means toward those goals—building the collection, providing reference service, creating efficiencies in

[17] Castells, *The rise of the network society* (Malden: Wiley-Blackwell, 2012).

technical processing and so on. This was the focus of professional practice and education. Much of this work is inherently bureaucratic. However, as goals shift in a changing environment, so does the need to think about how to marshal the means to meet them. This may require reorganization, new staff skills, changes in existing priorities, and reallocation of staff and resources. This requires a shift in culture from bureaucracy to enterprise, and the creation of a more adaptive organization that reviews and reshapes what it does in light of changing requirements.

Expertise

This in turn leads to a diversification of skills. As the library partners in research and learning, a broad range of competencies potentially come into play—pedagogy, copyright, marketing, exhibitions, digital asset management, data science and so on.

Systems

The focus of library automation has been on managing collections, and a sophisticated apparatus for managing print, licensed and digital collections has emerged. This is largely a back-office operation. In the services-based library, there is greater need for support for research and learning workflows, for building systems around communities and people as well as around collections. The library provides advice and consultancy about a range of other systems and services.

Space

With regard to space, buildings are historically configured around collections and their use. Nevertheless, libraries are increasingly being configured around user experiences. This means that libraries are reflecting on what collections should be maintained locally, taking a more specialized view of this.

Collections

We have spoken about the changing nature of collections throughout this chapter. To some extent, the familiar continuity of the view of the library shelves, or the library search box, obscures the multiple ways in which

library support around the creation, management and discoverability of content has changed.[18]

Some of the changes we have noted regarding collections are:

1. facilitated collections: A shift from just in case collecting to more of a just in time or facilitated approach. This includes a move to patron-driven acquisition and considerable effort devoted to providing guided access to materials outside the library (e.g., resource guides, etc.);
2. collections as a service: The collection anchors important services, but increasingly other services are also important. Many library services are not collection-based;
3. collective collections: There is a move to collective management of print collections. At the same time, there is a recognition that digital collections need to be aggregated for discovery purposes for maximum impact.

From consumption to creation: The library provides support for creation of resources in a digital environment, as well as their consumption. This may be support for digital scholarship, video production, creation of learning materials and so on.

The Services-Based Library

As the transition we have spoken about continues, the library story changes. One of the current challenges for the library is articulating that new story. We spoke about identity, value and workflow above. Libraries are forging a new engagement-based identity which is not anchored in a building or a collection, but rather as a partner in the creative process of learning and research. There is also an active value discussion, as libraries explore how to define value not in terms of inputs (e.g., the size of collection and gate counts) but in terms of impact. Libraries are building services around the network-based workflows of their users, and those workflows encompass many information resources alongside those acquired by the library. This means that the presence of the library becomes more diffused. Does the library user recognize, for example, that a journal article is actually accessible to them because of a library subscription?

[18] Lorcan Dempsey, Constance Malpas, and Brian F. Lavoie, "Collection directions: the evolution of library collections and collecting," *portal: Libraries and the Academy* 14, no. 3 (2014): 393–423; Dempsey, "Library Collections in the Life of the User: Two Directions."

Against this background, it becomes important for the new library story to be compellingly told. And important that library staff be visible in campus discussions, committees, research projects and classrooms. For convenience of designation, we refer to the evolving library as the services-based library, acknowledging that this is a somewhat general characterization. However, for our purposes here it is convenient as a way of contrasting with the collections-based library of the past.[19] As the library becomes more deeply engaged in the research and learning behaviors of its community, it is not surprising that we see greater diversification, as the communities that libraries serve are different. We now turn to a discussion of how those university and college communities are in fact diversifying, and in turn refocusing the library service profiles within their institutions.

Institutional Typology: Capturing Diversification

Analyses of the higher education sector in the United States typically rely on one or both of the institutional taxonomies developed by the US Department of Education's National Center for Education Statistics (NCES) and the Carnegie Foundation. These provide a sector-based view of the institutional landscape, categorizing universities by control (public, private) and levels of degree conferred. Though widely used, these taxonomies fall short of representing the diversity and increasing stratification of post-secondary education.[20] Some years ago, a study by the Chronicle of Higher Education proposed a more dynamic framework based on university business models.[21] This had the advantage of seeing universities as evolving, rather than as static members of a class. However, it was a basic model and has not been updated since 2009. Nor has it been widely picked up or operationalized. Simply, it proposed two models which it saw as thriving (elite and convenience), and suggested that those institutions in the 'middle', who tried to be all things to all people, would have to specialize more in order to succeed.

[19] For some discussion of a turn to services, see: Scott Walter, "'Distinctive Signifiers of Excellence': Library services and the future of the academic library," *College & Research Libraries* 72, no. 1 (2011): 6–8.

[20] Brian Prescott, "Thinking Anew About Institutional Taxonomies" (paper, Mapping Broad-Access Higher Education Convening at Stanford University, Stanford, CA, November 22, 2011).

[21] Martin Van der Werf and Grant Sabatier, *The College of 2020: Students* (Washington, DC: Chronicle Research Services, 2009).

As part of our ongoing research project with colleagues at Ithaka S+R, OCLC Research has developed a working model to help explore the diversification of university activity in the United States. Our approach is data driven, and relies on national survey data compiled by the US Department of Education in the Integrated Postsecondary Educational Data System (IPEDS).[22] Using data from the 2015 survey cycle, we have computed institutional profiles for 1500 colleges and universities, focused on two primary dimensions.[23] The first dimension characterizes the balance of institutional attention devoted to research (specifically, doctoral-level scholarship), liberal education (arts-and-sciences-focused baccalaureate education) and career preparation (professional degree and non-degree certificate programs). The second dimension characterizes the mode of educational provision, on a continuum between traditional residential programs designed for full-time, on-campus students and more flexible offerings designed for 'new traditional' students, including part-time, adult and distance learners. Here, we focus on our analysis of the first dimension, exploring directions in educational activity.

Applying this working model to a large segment of the US higher education sector, as we have done, makes it possible to distinguish important differences in institutional direction. A key benefit of our multi-dimensional analysis is that it readily enables visualization of institutional types based on the relative emphasis of educational activity and mode of provision. Figure 4.2 shows an application of this kind of visualization, comparing average values for two different cohorts with distinctively different institutional profiles: members of the Oberlin Group association of liberal arts colleges and members of the Association of American Universities (AAU), which gather leading research universities in the United States. While differences between liberal arts colleges and elite, research-intensive universities are widely recognized and could be easily intuited, our model provides a means of measuring and comparing the strength of institutional types across different populations. It is possible to explore both the significance of institutional isomorphism in the US higher education landscape (the

[22] "Data Submission Requirement," National Center for Education Statistics, accessed December 28, 2017, https://surveys.nces.ed.gov/ipeds/.

[23] Our current study is limited to non-profit (private and public) institutions, excluding community colleges. Our project population of 1500 institutions represents about a third of the US post-secondary population, representing colleges and universities that meet our scoping criteria, for which sufficient 2015 IPEDS survey data were available for analysis.

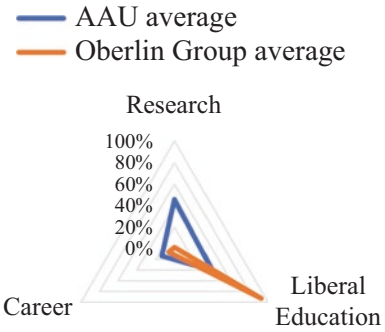

Fig. 4.2 Comparison of institutional profiles between the AAU and Oberlin Group

strong conformance to type exhibited within cohorts) and the diversity of institutional identity within those 'strongly typed' patterns.

A further value of our model is that it supports comparative analysis of institutional directions along multiple lines of business in which colleges and universities typically engage.[24] As post-secondary institutions adapt to evolving market needs (adding new professional master's programs to an established undergraduate education program, for example), academic libraries will need to tune and refine their services to support diversifying institutional needs. Even within institutional cohorts with a strong shared identity, such as the Oberlin Group, our model reveals significant diversity of institutional purpose. As Fig. 4.3 shows, there is substantial variance around the mean (average) values for the group, with some Oberlin Group members exhibiting significant institutional activity around career-related programs, while others exhibit a narrower focus on the interdisciplinary arts and sciences baccalaureate that is commonly viewed as the hallmark of liberal arts college education.

It is important to consider the implications of this diversity for models of academic library service, and benchmarks for library evaluation. While the familiar Carnegie Classification of postsecondary institutions has undergone multiple revisions in recent years, it is still common for US

[24] We do not pretend that the three lines of business (research, liberal education, career preparation) addressed in our model provide a comprehensive view of university activity. For instance, community engagement is a strategic priority for many colleges and universities, but is not represented in our framework. Because our model is derived from statistical indicators captured in the national IPEDS survey, we are limited to analysis of activities for which statistical variables have been defined or can be readily derived.

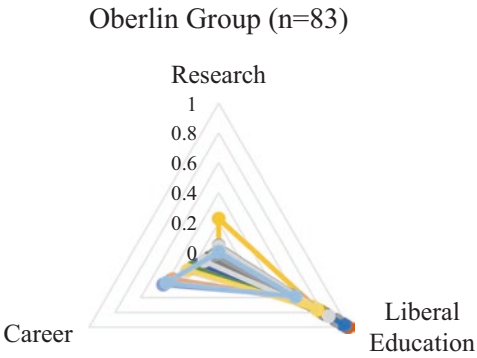

Fig. 4.3 Variance in institutional purpose within the Oberlin Group

libraries to rely on service benchmarks based on average values for 'basic' Carnegie classes such as Masters/Medium or Doctoral/Moderate Research Activity.

Yet, the library needs of a research university—of any size or intensity of research activity—with a significant commitment (and reputational stake) in liberal education of undergraduates, will differ from those of a research university focused more strongly on graduate education, or indeed a research university that is diversifying its offer to include more professional masters programs. Similarly, a liberal arts college with a burgeoning online master's or adult degree-completion program will have different library needs than a liberal arts college that has retained a focus on residential learning tailored to the needs of 'traditional' full-time students. Ongoing demographic change in the undergraduate enrollment pipeline is likely to accelerate the diversification of post-secondary educational offerings, with knock-on effects on the organization and provision of academic library service. Similarly, a shift from a residential focus to more convenience-based offerings potentially calls for a different approach to library services, a more focused tailoring around course requirements or greater visibility in learning and teaching workflows.

Academic Libraries in a Diversified Higher Education Sector

While research on higher education has clearly identified a need for increased attention to increasing differentiation in the post-secondary landscape, we have already noted how discussions about the future of aca-

demic libraries still generally rely on broad characterizations of the higher education enterprise. Assessment still tends to emphasize the means of the academic library, rather than the ends it serves. Consequently, there is not much attention to efficiency as a measure of success, nor is there attention to the different needs and expectations of different kinds of parent institutions. Of course, this is recognized and it is one reason that we have seen increased discussion of library value in recent years.

For example, recent work at ACRL has focused on library support for student success and increased library engagement in support of research, teaching and learning.[25] As accreditation standards emphasize the importance of aligning library collections and services with local institutional priorities, it is likely that there will need to be greater attention to prevailing patterns of need (or models of service excellence) in different institution types. Our effort to delineate different institution types based on the relative distribution of activity in research, liberal education and career preparation is intended to support a broad discussion of future library directions in institutions that will look less similar in the future than they do today.

It is clear that libraries in different types of universities already make investments in different types of services. However, it is likely that increased diversification of higher education institutions will drive increased diversification of library service models. For example, a research library will have strong incentives to provide support for emerging forms of digital scholarship, and to provide curatorial services for a broad range of research outputs (as per our discussion of the inside-out library above).[26] A library in a teaching-focused institution may invest more in services supporting

[25] Association of College and Research Libraries, *Academic Library Impact on Student Learning and Success: Findings from Assessment in Action Team Projects* (Chicago: Association of College and Research Libraries, 2017).

[26] Recent work by Carol Tenopir and colleagues has established a statistically significant relationship between the size of an academic institution and the robustness of the library research data management (RDM) service offering. Institutions with a full-time student enrollment greater than 5000 were observed to offer a broader range of consultative RDM services than smaller institutions. See Carol Tenopir, Ben Birch, and Suzie Allard, *Academic Libraries and Research Data Services: Current Practices and Plans for the Future: An ACRL White Paper* (Chicago: Association of College and Research Libraries, 2012). While we do not regard institution size, in isolation, as a reliable indicator of distinctive university type (for the purposes of our project), the positive correlation between institution size and RDM service portfolio is noteworthy.

student success.[27] Some libraries will assume responsibility for the print scholarly record; others will gradually divest.[28] Likewise, the sourcing of core services will vary: some will be internalized and promoted as institutional differentiators; others may be externalized to third parties.[29] And, as noted above, universities that are supporting an increasingly diverse range of educational offers may require multiple bundles of library service, and source those services through a variety of arrangements.

Returning to the three areas of institutional activity captured in our working model, it is useful to consider the alignment of some of the library services we have spoken about with university directions. Research-intensive universities increasingly expect libraries to provide support for emerging disciplinary workflows (electronic laboratory notebooks, computational approaches to textual analysis) alongside support for traditional, paper-based workflows. Research libraries may also have a role in supporting the university research enterprise through implementation and support of research information management systems (or CRISes) to automate faculty performance review, promotion and tenure. Comprehensive universities that combine high levels of research with large-scale undergradu-

[27] For example, DePaul University library has integrated library-based support services into the local implementation of Starfish, a commercially licensed learning analytics and student retention system. See: Scott Walter, "Library Research Services Now Available in BlueStar," October 17, 2016, https://news.library.depaul.press/faculty/2016/10/17/library-research-services-now-available-in-bluestar/. A growing number of college and university libraries now offer specialized student success services designed to increase student engagement and achievement. This trend is explored in a 2015 blog post by Steven Bell in Bell, "AKA 'The Student Success Center,'" *Library Journal*, July 8, 2015, http://lj.libraryjournal.com/2015/07/opinion/steven-bell/aka-the-student-success-center-from-the-bell-tower#_.

[28] Until very recently, the only libraries registering explicit retention commitments for print collections in the WorldCat union catalog were large university research libraries. As more shared print partnerships emerge, with broader representation of the academic library community, we expect to see a mix of institution types participating in distributed retention programs. For example, the Eastern Academic Storage Trust initiative includes many liberal arts college and mid-size university libraries as retention partners. See "Members," Eastern Academic Scholars' Trust, accessed January 11, 2018, https://eastlibraries.org/members. As part of the proposed project, we plan to investigate how different library types perceive their institutional responsibility to preservation of the print record.

[29] We explore institutional choices about internalizing or externalizing research data management capacity in *The Realities of Research Data Management*, a four-part series of reports from OCLC Research. See: "The Realities of Research Data Management," OCLC, accessed December 28, 2017, https://www.oclc.org/research/publications/2017/oclcresearch-research-data-management.html.

ate education may look to the library for support with data-driven analytics of teaching and learning outcomes. Institutions that specialize in undergraduate liberal education will have less need for library support for research workflows or related infrastructure, but may expect the library to take a leadership role in the selection and implementation of e-portfolio systems for managing and tracking student learning outcomes, or supporting faculty use of open educational resources. Colleges and universities with a career-directed outlook will typically require library support for digital information literacy, access to core collections and workflow and other tools to support student success (assignment calendars and other time-management tools, academic coaching services).

Based on the patterns noted here, it is possible to abstract a general picture of emerging service models in different academic settings that is largely borne out by empirical observation. Academic libraries in research-intensive institutions are increasingly preoccupied with support for digital research workflows and are making substantial investments in appropriate software and services, alongside continued investment in traditional, collection-centric activities. College and university libraries in institutions with less graduate-level research have less robust research data management infrastructure, for example, but position themselves more explicitly as partners in instructional design and collaborative learning. Libraries in institutions that are pivoting toward more career-directed programming are creating space for career counseling services within the library, aligning library services with 'real world' work experience and promoting the library as a partner in preparing for life after college. These service patterns reflect strategic choices that promote increased alignment of library activity with broader institutional interests and over time will result in a more diversified academic library landscape.

Nevertheless, services-oriented libraries take directions in different institutional settings. Some emerging service areas are shared, but most are not (see Table 4.2). This is a reflection of the diverging institutional identities and interests of colleges and universities seeking to differentiate their educational offer to compete for enrollment, revenue (tuition and research funding) and reputation. In a services-oriented environment, the library's identity and value are associated with the specialized research, teaching and learning workflows it supports. And with more institutions striving to identify a distinctive niche in which to succeed, we can anticipate that academic library models will look more different than alike. There will be multiple models of library excellence, but also limited toler-

Table 4.2 Differing directions of a services-oriented library

	Research	*Liberal education*	*Career*
Emerging library services	Research data management (data repositories, data management plans, e-lab notebooks), research information management (tracking university research outputs), and data analysis and visualization	E-portfolios, open educational resources, library support for instructional design, integration of library content in institutional LMS, special collections integrated within undergraduate research programs	E-portfolio and fab labs
Staffing	Specialized research support librarians (including PhDs)	Student success librarian	First-year experience librarian
Shared infrastructure	Shared print repositories, shared research data repositories and consortial borrowing networks	Shared print repositories, shared OER repositories and consortial borrowing networks	'Library in a box' licensed collections, shared, multi-tenant ILS

ance for libraries that preserve or emulate a service model that is not a good fit with current institutional needs.

Conclusion

We have discussed how the academic library story has changed. Libraries are transitioning from a collections-based model to a more broadly services-based model. This is inevitable, as students, teachers and researchers inhabit a rich network information environment, and as their work is increasingly enacted in digital, network workflows. The library's role is no longer to assemble a large local collection. It is to support their users' creative activity in more diffuse ways—as a partner and an advocate. Of course, collections remain important as a component of a broader service array and the library role in licensing electronic materials is still central. This has been a gradual shift, and library identity, value and workflows are being refashioned.

We have also discussed how university emphases can be characterized in relation to three poles: research, liberal education and career prepared-

ness. At the same time, universities have different and evolving balances between residential and convenience orientations. While universities are complex organizations and are variably inserted in national policy or planning contexts, this model does provide a way of thinking about directional patterns. Importantly for our purposes it also provides a context for thinking about library directions.

In the collections-based environment (arguably superseded, but still influential in identity, value and workflow discussions), libraries shared many characteristics. As we move toward a services-based library which values strong engagement with its home institution, it is natural for libraries to diverge more, in line with the character of those home institutions. Of course, this is within a broadly familiar envelope of services, but emphasis and priority shift. This means that models of excellence also shift, as value is not assessed in terms of collection size or gate count, but in terms of fit to the goals of the home university. This is a great moment for university libraries—as they redefine what it means to support the research, teaching, learning, and engagement goals of their universities and colleges.

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PART II

How Education Has Begun to Adapt: Case Study Assessment

CHAPTER 5

Innovation Education in China: Preparing Attitudes, Approaches, and Intellectual Environments for Life in the Automation Economy

Rosaline May Lee and Yanyue (Selena) Yuan

The Ninth Five-Year Plan explicitly made reform aimed at improving the quality of education a core priority.[1] Since then China has allocated an ever-increasing percentage of its budget to education; in 2015 that expenditure reached 4.26% of the country's GDP. Ten years ago, the effort focused on the basics—infrastructure and faculty hiring. At the university level, this meant building better labs, hiring more faculty, updating and improving buildings, and so on. Five years ago, as more Chinese middle-class parents began to send their children abroad for school, universities and high schools began to focus more closely on content and curriculum. Popularization of the 'Tiger Mom' in the United States with its

[1] In 1999, the 3rd National Conference on Education was held where the goal of promoting quality-oriented education (as opposed to exam-oriented education) and innovative capacity was raised.

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accompanying sense of insecurity about the rigor of US education stimulated an oddly complementary reaction in China in the form of an insecurity about the adequacy of China's education in the twin realms of creativity and innovation. Countries worldwide realized that the main sources of job growth would come through innovation and entrepreneurship. The pressure was felt most strongly in the education sector.

The Chinese response to the need to create a culture of innovation and entrepreneurship has been significant. In a few short years, the phrase 'Chinese Innovation' has gone from meaning copying Silicon Valley to fears of China surpassing Silicon Valley. Every day, we read another case study about Chinese innovation, the omnipresence of weChat, China's leading position in mobile payments, fintech, Alibaba, and China's emergence as a leader in fields such as artificial intelligence and machine learning. The challenge that remains here, however, is maintaining the momentum and that involves creating a culture, or ecosystem (生态), of creativity, critical thought and entrepreneurial spirit. These environments are created by practices developed early in life and deeply influenced by the social, economic, and educational institutions young people and young adults come into contact with. No institution is more important to developing a culture of creativity and innovation than school. In China, this has led to a fundamental revamping of its educational system. This is a grand project requiring sustained effort and persistence. It is also a project that requires a reset of 'software' (i.e., attitudes, approaches, and intellectual environment).

China's success at modernizing over the last 30 years has followed a consistent pattern comprising investigation of best-in-class models from other countries, experimentation in China (usually involving a wide range of permutations and varying degrees of localization), and then mass adoption through government edict or market demand. In this chapter, we describe the state of current higher educational reform efforts in support of innovation; explore the obstacles facing far reaching reform, offer a view about the likelihood of success, and the potential emergence of a 'Chinese model' for innovation; and identify some lessons other countries might draw from China's experience. We use our own experience, introducing and teaching 'Design Thinking' to STEM students at a Chinese university as a case study.

Innovation Education in China

Innovation: A Buzzword in China and Its Intersection with Education

At the 2014 Davos Forum, Premier Li Keqiang introduced the slogan 'Mass Entrepreneurship and Innovation' and by 2015, innovation and entrepreneurship had been officially celebrated as an important part of national policy (e.g., the word 'maker' appeared in government report in March 2015).[2] Statistically, China can take pride in its progress since the formal invocation in 2015. The Global Innovation Index ranks China at 25 in 2016, scoring at 50.60.[3] This marks a material change compared to its rank of 29 with a score of 47.47 in year 2015.[4] The Report of National Innovation Index 2016–2017[5] rates China at 17 among the 40 countries it investigates (compared to 19 in 2014), a leading position in the second tier, a meaningful improvement in a short time.

It is impossible to appreciate or explain the nature of China's investment in developing a culture of innovation and creativity while ignoring the fact that China is fundamentally a centrally planned economy. For national priorities, the Central Government disburses funds to the provinces and so on to the smallest administrative unit. Thus, one can observe even the smallest district in China encouraging 'Ten Thousand types of Entrepreneurship and Innovation' (万众创新) as manifested in the mushrooming number of fab labs, makerspaces, co-working spaces, hackerspaces, incubators, and accelerators. Lego classes for creativity and hackathons occur multiple times per day all over the country.

Our focus here is on the development of this culture in universities across China. In keeping with the government mandate, universities across the country have created new schools dedicated to innovation named

[2] Tsinghua University, Modern Educational Technology, Intel Corporation, "Zhongguo chuangke jiaoyu lanpishu" [China Maker Education Bluebook 2015], 2015, https://www.intel.cn/content/dam/www/public/cn/zh/pdfs/csr-maker-education-2015-bluepaper.pdf.

[3] "Indicator Rankings and Analysis," The Global Innovation Index, accessed January 10, 2018, https://www.globalinnovationindex.org/analysis-indicator.

[4] The Global Innovation Index, "Indicator Rankings and Analysis."

[5] Chinese Academy of Science and Technology for Development, "Guojia chuangxin zhishu baogao 2016–2017 tujie" [National Innovation Index 2016–2017 Infographic], last updated August 8, 2017, http://www.casted.org.cn/channel/newsinfo/6336. The Academy has been issuing annual reports on national innovation index since 2011.

'School of Innovation,' 'School of Innovation and Entrepreneurship,' or 'School of Entrepreneurship and Management,' both within and out of extant business schools. The number of incubators has increased by 18% with 20% more space. Meanwhile, funding for innovation and entrepreneurship within and out of university has reached RMB 1.02 billion and RMB 1.28 billion respectively. More than 3 million university students are engaged in entrepreneurship and innovation events.[6] Conferences on innovation and entrepreneurship are hosted at universities multiple times per week. Here we see the first example of following well-trod paths from existing innovation ecosystems: using Silicon Valley (including Stanford), Israel's Technion, and MIT as models, the first prong of China's efforts focuses on the hardware supporting innovation. The underlying principle can be summed up as: If you build it, they will come.

Chinese universities have also initiated efforts to cultivate connections between universities and industry. Looking again to the example of US universities, Chinese universities undertake these partnerships to facilitate innovation moving from basic bench research to commercial application. They have created Tech Transfer offices that liaison with industry. New policies governing faculty inventions are being considered as is the challenge of allocating Intellectual Property (IP) ownership created by government funding.

From a policy perspective, the Ministry of Education (MOE) has issued specific policies to support innovation and entrepreneurship, including a policy allowing students to take one year off to pursue an entrepreneurial venture.[7] In 2015, the MOE suggested all universities provide eligible courses in entrepreneurship for credit (compulsory and selective) to all students.[8] By 2016, 82% of Chinese universities had introduced compulsory and elective courses in innovation and entrepreneurship (an increase

[6] The statistics were provided by Mr. Wang Lin from the Ministry of Education (China) at the International Forum on Innovation and Entrepreneurship Education at Renmin University of China, Beijing in October 2015.

[7] Ministry of Education China, "putong gaodeng xuexiao xuesheng guangli guiding" [Regulations for Ordinary Institutions of Higher Learning], February 16, 2017, http://www.moe.gov.cn/srcsite/A02/s5911/moe_621/201702/t20170216_296385.html.

[8] Ministry of Education China, "jiayubu guanyu zuohao 2016 jie quanguo putong gaodeng xuexiao biyesheng jiuye chuangye gongzuo de tongzhi" [Notice from the Ministry of Education regarding jobs and entrepreneurship for graduates from Ordinary Institutions of Higher Learning in 2016], December 1, 2015, http://www.moe.edu.cn/srcsite/A15/s3265/201512/t20151208_223786.html.

of 14% compared to the previous year). Similar reform efforts and investments in the spheres of vocational education and the equivalent of community colleges are also ongoing in China. Innovation education and its accompanying activities are occurring at every level of post-secondary education.

Finally, over the past eight years, the MOE encouraged Sino-foreign joint ventures between universities, as well as the establishment of private universities. These new players introduce new thinking, new systems, and new pedagogy into the DNA pushing local institutions to experiment and change. NYU Shanghai,[9] Duke Kunshan, Carnegie Mellon's efforts with Sun-Yat Sen, and Kean are among the more well-known recent efforts. Johns Hopkins' program with Nanjing University is the oldest existing program in China. While these initiatives are important, the balance of our discussion focuses on efforts within traditional institutions of higher education—Chinese research universities.

Observations on Two Curricular Trends in Support of Innovation

Investing in space, partnerships, and conferences is one thing. Adjusting curriculum and pedagogy is another kind of animal entirely. Teaching and applying innovation is not simply a 'lessons taught-skills acquired' process. Nurturing innovative capacity requires long-term and sustained efforts. We have noticed two related trends within Chinese universities that may have an impact on improving student capacity for innovative thinking.

The first noticeable trend is the renewed attention and trend toward 'general education' (通识教育).[10] Institutions such as Tsinghua University, PKU, and Zhejiang University (to name just a few) have liberal arts programs designed to give students a strong foundation in critical thinking and analytical skills as well as broaden students' mind.[11] Ironically, this takes place at the same time when the United States shows signs of turning away from liberal education. Fareed Zakaria in his book *In Defense of a*

[9] The author, Rosaline May Lee, spearheaded this project as Vice-Chancellor for Asia at NYU.

[10] This term is often used synonymously with liberal education and quality-oriented education, the latter is more widely applied in the context of elementary and middle-level education.

[11] See Appendix A for examples of such programs.

Liberal Education makes a case for revitalizing and reemphasizing liberal education, as a method to teach one how to write, how to speak your mind, and how to learn rather than simply empowering one with expertise knowledge and professional skills. He quotes Drew Faust, President of Harvard University, in which a "liberal education should give people the skills that will help them get ready for their sixth job, not their first job."[12]

According to the Association of American Colleges and Universities (AACU), the goal of a liberal education is to "help students develop a sense of social responsibility, as well as strong and transferable intellectual and practical skills such as communication, analytical and problem-solving skills, and a demonstrated ability to apply knowledge and skills in real-world settings."[13] While China's leadership has expressed a desire to instill social responsibility and innovative thinking in its students, it is unclear if the Chinese model will follow the Western tradition with its educational philosophy of breaking boundaries, cultivating a humanistic vision, and strengthening intellectual capabilities. In the West, this occurs through the close reading of text, robust disagreement, and intense (if respectful) questioning of authority under the guidance of a professor. It is difficult to read text closely, for example, when the text itself is controlled as is often the case here in China.

Coupled with the initiatives to inculcate the DNA of liberal education into undergraduate education, encouraging interdisciplinary research and study has also become popular. It is viewed as an essential feature of liberal education, but of course, this is no panacea to the challenge of teaching innovation. The same critique can be applied to offerings of new courses and degrees in correspondence with technological revolutions that are taking place. For instance, universities around the world have started to provide courses, degrees, and certificates in areas of data science (big data) and machine learning.[14] There is a danger, however, that these responses might overshadow the more long-term and essential goal of nurtureing the fundamental qualities required to innovate, including critical thinking, imagination, readiness for change, open-mindedness, and a high tolerance for uncertainty and resilience.

[12] Fareed Zakaria, *In Defense of a Liberal Education* (New York: W.W. Norton, 2015), 75.

[13] "What is a Liberal Education?," Association of American Colleges and Universities, accessed January 10, 2018, https://www.aacu.org/leap/what-is-a-liberal-education.

[14] Ryan Swanstrom, "Colleges with Data Science Degrees," April 9, 2012, http://101.datascience.community/2012/04/09/colleges-with-data-science-degrees/.

At this point, we switch our focus to exploring the ways in which the government mandate, which requires a culture of innovation and creativity, has played out in our experience in the School of Entrepreneurship and Management at ShanghaiTech University.

Case Study: Teaching Design Thinking in a Chinese University

We set our case study against such background, as ShanghaiTech is itself a brand-new university born out of the above trends.[15] The university eschews traditional departments in favor of broad-based schools. For example, the School of Physical Sciences includes the disciplines of physics and chemistry as well as many of the corresponding interdisciplinary sub-disciplines such as materials sciences and nanomaterials. Our students must take a broad range of compulsory courses in the humanities and social sciences. Each summer, students must engage in an experiential learning project.

Our journey of teaching 'Design thinking: Applied Innovation' demonstrates the potential and difficulties of launching innovation education in China. It also offers lessons in how innovation education might be adapted to specific contexts. More significantly, we share our reflections on how our observations can offer insight into China's preparation for the fourth industrial revolution (4IR) and whether China can innovate in a way that promotes future economic growth and employment.

Why Design Thinking?

The origin of 'design thinking' as a distinctive field of enquiry or subject can be traced to Herbert Simon and Robert McKim. Thereafter, a variety of architects and designers began to explicitly examine, analyze, and explain the methodology of design. Eventually, a group of designers drew a connection between the theory of design thinking to the idea of 'wicked problems' as a prominent feature of social enquiry.[16] Wicked problems are those issues that

[15] The university website states "the University seeks innovative solutions to address the challenges that China is facing in the field of energy, material, environment, human health, thus to improve productivity driven by innovation, and contribute to the restructuring and development of China."

[16] Horst W. J. Rittel and Melvin M. Webber, "Dilemmas in a general theory of planning," *Policy Sciences* 4, no. 2 (1973): 155–169.

cannot be readily defined and exhibit high level of complexity, interconnectedness, multiplicity, and fluidity. These problems, therefore, cannot be tackled with traditional linear scientific methods and they do not lend themselves to singular 'correct' solutions.[17]

David Kelly, co-founder of IDEO and founding dean of Stanford's d.school is credited with popularizing design thinking. Over the past two to three decades, design thinking has been taught to students from diverse disciplines with the aim of developing a set of capabilities to tackle large intractable social problems. Indeed, more and more, people use design thinking as a proxy or synonym for innovation. *Harvard Business Review* dedicated the September issue of the 2015 to design thinking and in his article 'Design Thinking Comes of Age,' Jon Kolko heralds design thinking "as an essential tool for simplifying and humanizing. It cannot be extra; it needs to be a core competence."[18]

Four years ago, in my capacity as the Dean of the School of Entrepreneurship and Management, I recommended we incorporate design thinking as a core curricular requirement. At the time, design thinking had yet to arrive to China's shores. ShanghaiTech was the only university in China to mandate such a course and we have made it a centerpiece of our effort to educate innovative talents.

Our initial goals for the course were:

1. offering the students an experiential-based course to learn the human-centered design process;
2. expose the students to real-world problems;
3. provide the students with an entry point for thinking about innovative approaches to problem-solving in business settings.

The ultimate goal of our course is ambitious, that is, to plant an innovation or entrepreneurial seed in these science and engineering students among whom some might become leaders, entrepreneurs, policymakers, or play other key roles in promoting innovative business and enterprises using 4IR technology, with the mission of bringing about true innovation and a sense of social responsibility.

[17] For an abbreviated but interesting history of design thinking, you can consult Natasha Jen, "Design Thinking is Bullshit," filmed 2017 at 99 U Conference, New York, New York, video, 13:27, http://99u.com/videos/55967/natasha-jen-design-thinking-is-bullshit.

[18] Kolko, "Design Thinking Comes of Age," *Harvard Business Review*, September 2015, https://hbr.org/2015/09/design-thinking-comes-of-age.

(Re) Learning the Localization Lesson

Initially, we offered Stanford d.School's standard syllabus (with a few concessions to local context) and immediately faced a number of challenges. The students' attitude toward the course posed the initial obstacle. Their reactions ranged from 'Why do I need to study design?' to 'What a terrible waste of time.' While students often have this reaction to mandatory core courses, we find more cause for concern from the results of an informal learning assessment at the end of the school year: the data show unequivocally our students have not internalized the learning outcomes for use in other contexts.

The evolution of this course is itself a design thinking process. As we reflected upon this first iteration, we concluded one characteristic of our learners is their almost complete lack of exposure to the real world and predisposition toward a pragmatic worldview. Students cared about whether the class would help in their majors, provide a skill to improve the odds of obtaining a job, create a credential to facilitate admission into graduate school, and the effect of the class grade on their Grade Point Average (GPA). Most of our students grew up going to school, studying, doing well on standardized tests, and repeating that cycle until admission to university. They had little grasp of practical life.

As a result, we devised a different entry point into design thinking by linking the content to the student's life experience hoping to pique their curiosity and using those experiences as the starting point for a class project. Our second prototype of design thinking, therefore, highlighted the creating solutions aspect of design thinking. With this change, we hoped students would find the course more attractive and engage their creative abilities. While students expressed more interest in the course, one unintended consequence of our new approach emerged: the emphasis on solutions fed into our students' training and reinforced their tendency to look for the single correct answer—exactly the opposite of what we hoped to achieve. Though the faculty emphasized the goal of the course lay in the journey of searching for the solution through inquiry, students paid no attention. Instead, they placed maximum value on generating a solution, viewing the design thinking process through the same lens as learning the process to solving a differential equation. In their minds, the answer was what mattered.

In the final analysis, the students' inability (or unwillingness) to ask questions meant that they did not grasp the fundamental purpose of design thinking to identify a hidden core user need (problem) rather than

accepting the obvious articulated user need. For example, one team of students decided to look at the issue of insufficient lockers at the university. After two weeks of user research, surveys, and interviews, the team came to office hours with the following question: "We don't understand the point of this exercise. Isn't the solution to our problem simply adding more lockers?" It never occurred to them to look at whether demand for the lockers fluctuated, and if so, the reasons for the fluctuation. Nor did they investigate what percentage of the students used the lockers, why students used the lockers, and how they used the lockers.

Overcoming the 'Software' Obstacle: Pinning Down Our Teaching Philosophy

As we reviewed the problems we encountered,[19] especially the mismatch between our goals and the students' performance and mindset, we further revised our course design. This time we localized our core teaching philosophy. We combined experiential learning with traditional test-taking, short lectures with interactive exercises, and, most importantly, emphasized academic rigor throughout every phase of the design thinking process. We chose to deliver the course in workshop style divided equally across lectures, in-class exercises, and project time in and out of class. In this 'east meets west' approach, we allowed our students to engage with pedagogy familiar to them while slowly introducing and guiding them through the more experiential self-directed segments of the course.

We introduced academic rigor by making critical thinking a primary feature of our course. The course begins with an introduction to critical thinking as a foundation for the balance of the course. Students learn the role of assumptions (identifying and questioning); the distinction between causation and correlation; the centrality of defining terms and other basic tools of reasoning. Using this knowledge as a springboard, students learn the fundamental tools and processes of design thinking with an emphasis on identifying and reframing the problem (rather than solving the problem), identifying user needs, and grasping the concept that more than one right answer exists. Throughout, students also work on connecting critical thinking to design thinking. It took a lot of effort to lead our students

[19] Apart from debriefing and brainstorming, we also collected and analyzed students' feedback through short surveys and informal conversations with students both individually and in groups.

who are immersed in scientific issues to identify wicked problems. Students came to design thinking with two critical preconceived misunderstandings: the first was that technology and solutions were synonymous (rather than conceiving of technology as a tool to achieve a solution); the second was a firm belief in the existence of a singular correct solution.

Traditional design thinking processes yield valuable insight during the user research phase, both in terms of identifying a core need, as well as potential solutions. These courses begin with the premise of human-centeredness: find the human side of the equation and potential solutions present themselves. The bias toward technology meant our students had no context for understanding human-centered design or empathy. We quickly realized we could not simply mention the concept empathy to students with the hope that they would make the connection to users' needs. We thus framed identifying user needs as an exercise in critical thinking, as well as learning how to apply basic social science research methodologies.

Finally, we made teamwork the core of the students' experiential journeys. Our students have very little experience working together in teams. All exercises required teamwork and assessments made primarily based on teamwork outcomes. They often expressed frustration with teamwork, insisting they could work more efficiently as individuals. More critically, our student teams tended to focus on attaining consensus at the very outset of a process. We call this a tendency to collaborate for consensus rather than for innovation. We wanted, however, to challenge them to collaborate as teams and hold each other accountable, which mirrors how they are expected to work in the real world. Thus, for example, we introduced the concept of teams by challenging the students to define team, teamwork, the value of a team, and eventually requiring them to create their own team norms.

An Adapted Course Structure

Design thinking traditionally consists of five modules: Empathize, Define, Ideate, Prototype, and Test. The five stages do not require linear or sequential execution. They do, however, require iteration, repetition, and most of all, enough time. Considering our course takes place over 8 to 16 sessions during a 4- or 8-week term, we restructured to coincide more closely with our learning objectives: Define, Reframe, Ideate. We tell the students this course requires them to identify an issue and verify assumptions through an

understanding of human behavior. The students are mainly assessed by a final project requiring them to articulate their journey to finding an appropriate issue; their proposed solution only counts for one-fourth of the final presentation grade. We teach in both English and Chinese (all course materials are in English) and ask the students to try and present in English but do not require it.

This new three-stage framework has multiple benefits. First, it emphasizes the role of critical thinking in design thinking. Second, students experience first-hand the importance of verifying assumptions and the consequences of false assumptions. Third, by identifying a problem in relation to real-world users, students can establish a link between critical thinking, human behavior, and human-centeredness.

In the Define segment, we require the students to connect their newly learned critical thinking skills with design thinking. The students analyze the meaning of teamwork, what it means to work in teams, and select a problem, as a team, to solve. For example, we use the 'Desert Island Challenge'[20], which poses an unusual hypothetical situation, to give them experience working as a team.[21]

Define essentially encompasses 'sensing,' a traditional design thinking process, where students collect data through field research and desktop (primary) research. We teach them techniques such as mind-mapping to enhance brainstorming sessions, followed by desktop research and field research (mainly using surveys and interviews). Students must use their critical thinking skills throughout. In our revised syllabus, we reiterated the essential role of critical thinking when doing primary research. For example, when introducing research, we asked students to evaluate the nature and source of materials for reliability, identify the author's underlying assumptions, and strength of the arguments made. In terms of field research, we briefly introduce techniques of designing survey questions and open-ended interview questions. We plan to make further adjustment to provide students more guidance in this area.

[20] See Appendix B.

[21] A few teams surprised us by stating their goal to enjoy fully the last moments of their life, leading them to choose rum and cigarettes which they had never tried before. Another team decided their odds of survival were low and they hoped to express their love and care to their family, so they selected the ballpoint pen, magazine, and rum bottle to make a drift bottle with messages to family members.

Reframing is a concept borrowed from THINK[22] with the goal of "overturn[ing] conventional wisdom to discover new possibilities."[23] We task our students with a simpler objective: analyze their data and apply critical thinking to work out which initial assumptions they have verified and which they have disproven and consider how those assumptions change the nature of the problem they have chosen to solve. In essence, we ask them to reframe their initial problem through critical thinking and sensing. We teach them to use the classic design thinking formulation of 'How Might We …' which allows them to connect the problem and objective to a specific group of users. In fact, students must constantly engage in 'reframing' through the duration of class.

Outcomes and Lessons Learned

Outcomes

Happily for us, we saw a dramatic increase in students' interest in the course. Originally, more than 80% indicated zero interest in the course. As a measure of our progress, that number slipped below 20% in the Spring Semester offering early this year. Another indicator is the number of students who choose to take our upper-level innovation courses that is built on the skills gained during design thinking.[24] A surprisingly large number of students expressed interest in enrolling in our Minor in Innovation and Entrepreneurship, and most exciting, some students expressed their eagerness to work further on the project they developed during design thinking course. Overall, most students started to exhibit qualities of critical thinking by the end of the course. Through identifying assumptions and real-world research, they came to appreciate the value of technology as simply one of many tools to solve social issues. Design thinking aims to teach two primary lessons—human-centeredness and rapid iteration. In China, with the focus on rapid change, we realized our students needed to learn to slow dow.

[22] THNK is an institution based in Amsterdam, dedicated to training creative leaders with the goal of solving some of the world's biggest problems.

[23] THNK, 'About Us,' last updated December 21, 2017, https://www.thnk.org/about-us/. THNK is a creative leadership academy based on Amsterda*m* that "develop*[s]* and support*[s]* creative leaders around the world to find new solutions and opportunities to address the world's most persistent social challenges."

[24] In our school, we provide advanced-level selective courses in relation to entrepreneurship and innovation and completion of design thinking is a prerequisite of all these courses. Students can also choose to Minor in Innovation and Entrepreneurship.

Scaling

One other feature of the Chinese context is the scale. In most places, design thinking courses are limited to 30 or 40 students per course with multiple instructors. At ShanghaiTech, we must teach 300 students per year with a teaching staff of 4. Given that it is an obligatory course for freshmen, and STEM students have a very heavy course load, most students prefer to choose design thinking during the 4-week summer term. As a result, we often have a big class of around 150 students in summer, which on its face seems to minimize the opportunity for interactivity. We had no choice, however, but to reorganize the course—more short lectures, more mandatory office hours, and restructuring of in-class exercises. We introduced more peer-to-peer learning giving the students more access to a diverse range of ideas from their peers. We put together a group of instructors from diverse backgrounds (design, engineering, computer science, social sciences, and start-up businesses), exposing the students to multiple perspectives during the mini-lectures and brainstorming. These courses resulted in surprisingly positive outcomes.

Next Steps

We intend to continue refining our approach as we gain experience and insight into our students' needs. For example, during the 2017 summer session, we noticed our students often confused the concept of an assumption with making an assertion. Some students categorized their opinion as a singular assumption, thereby failing to understand their assertion included a number of assumptions. Critical thinking continues to be a challenge.

Similarly, students often conflate their solution with their 'how might we' questions. We realized we need to clarify the rationale for the construction of the question so that students might understand the requirement for specificity of target user, broadness of a problem while providing direction for potential solutions. Finally, our students still struggle with creating original solutions. For instance, not surprisingly, students tend toward smartphone apps as solutions.[25] We hope to find more examples and case studies of low-tech (or no-tech) solutions to offer as inspiration.

[25] See Appendix C for examples of student projects.

Most importantly, this course cannot have the impact it has in places such as Stanford or MIT as an isolated innovation. At present, SEM's tenure-track faculty participate by teaching the Critical Thinking Module, as well as offering advice for projects. SEM plans to provide training to faculty from other schools on design thinking in the hopes that eventually, faculty from all four schools will participate in delivering design thinking to ShanghaiTech's students.

Great potential also exists in terms of connecting design thinking directly to the students' other courses. For example, we have spoken with the School of Information Sciences (SISTI) about allowing SISTI students to connect the design thinking final project to a required project in the mandatory Introduction to Information Science course. As we gain experience, we intend to expand these types of connections.

We are also trying to link design thinking course to other activities at the university, such as the freshman social responsibility project (a mandatory course worth one credit). In the spirit of design thinking, we need to deepen our understanding of our students. What are they eager to know? Which topics are they interested and why? What kind of support do they need? The greatest challenge in delivering innovation education is to turn young learners' confusion into curiosity. They are not unwilling to learn, but it is incumbent upon us to find the appropriate starting point to facilitate the learning process.[26]

A Metaphor for the Future of Innovation in China

China's success over the last 30 years has been a constant process of learning from the West and scaling. Large infrastructure and urban development projects relied on a combination of massive government investment, Western know-how, training local teams, and a large labor force. Over time, as local engineering talent gained experience, China began to set the standard in areas such as high-speed rail travel. More recently, China's home-grown innovative companies, such as cTrip, Alibaba, DJI, and Tencent, have changed the paradigm for innovation by relying on the 'take and adapt' model: they have succeeded by taking Western business

[26] This summer, for example, we introduced a new course on designing computer games. The course focused on teaching the students to understand what makes a good game, the creation of a story, and the interaction between gamer and game designer. Many of these skills share an origin with design thinking.

models and adapting those to the needs of the local Chinese market. As China's requirements move from building things to building people, ecosystems, and cultures, this newer model has taken hold at the highest level.

China's leadership has expressed a desire to find a unique Chinese model in everything from financial systems to economic and political models, as well as education.[27] Our experience in education offers some hints as to how this process unfolds and its implications for what innovation might look like here in China. Moreover, the challenges we have met in China offer valuable lessons to the rest of the world in terms of promoting and sustaining innovation education.

Capital Investment Model and Scaling

When it comes to innovation education, China has taken concrete steps in the form of capital investments and policy changes to jumpstart innovation education at a massive scale. The country has committed to massive investments in higher education (and the research that supports these institutions) just as many more developed Western countries are moving to do the contrary. Many have written articles about the increased funding for science research, labs, and luring prominent academics (as well as recent graduates from PhD programs) back to China from overseas positions. While monetary investment is not a panacea, its existence certainly makes preparation for the 4IR more feasible.

Educational institutions endowed with extra funding for innovation have, in turn, initiated panoply of new programs, projects, and classes, with the only requirement that the endeavor include the words innovation and entrepreneurship. The quality of the programs and courses vary widely as does the quality of the faculty. If Western counterparts examine the course content and delivery, it will often look unrecognizable. The system sets numeric metrics for success, for example how many incubators, classes, students, and fab labs are present. None of the metrics explicitly address the quality of any individual initiative. This leads to many false starts and wasted resources.

On the other hand, China does not lack for capital and has the law of numbers on its side. A 1% success rate in China, on an absolute numeric basis, dwarfs numbers elsewhere (with the exception of countries like India and

[27] Bruce Fuller, "A Shifting Education Model in China," *The Atlantic*, December 14, 2015, https://www.theatlantic.com/education/archive/2015/12/china-education-system/420234/.

Brazil). With a population of 1.3 billion, having impact means doing things at exponentially larger scale than elsewhere. This type of scale allows for large numbers of experiments and more data points for success. The downside, however, is that a defective outcome in an experiment can often affect a large population. Innovation itself is about trying and often gaining surprisingly good results after multiple efforts. In this sense, China epitomizes at least one type of mindset required for the future: willingness to experiment, ability to incorporate learnings rapidly, and operating in uncertainty.

In short, the Chinese approach favors massive experimentation, wide beta in terms of results, resulting in a low rate of return on its investment. This approach is difficult to replicate in countries such as the United States with its wrangling over taxpayer dollars. Countries in Africa, elsewhere in Asia, and South America, on the other hand, could consider adopting a similar approach (although one must consider the variations in government control).

Isolated Efforts Do Not Equal Ecosystem Change

With three years' teaching experience, we have adjusted our course accordingly and have reached a clearer understanding of what we can do to push our students to think more critically and creatively. We feel confident in our short-term impact based on feedback, observed outcomes, and student involvement at SEM. However, we still face several challenges as well as some questions about longer-term impact. At the risk of stating the obvious, simply introducing design thinking as a compulsory course in universities cannot fundamentally help students to think more creatively. The changes that design thinking alone can bring are small and transient. We are aware that students need more support to help them through the transition from an exam-oriented didactic educational setting to an inquiry-based experiential learning environment. Our tech-savvy students possess the fundamental abilities to learn the skills and knowledge to thrive in the 4IR. But in order to bring fundamental change in support of innovation, understanding what and how is far from sufficient. They need to be able to think about and figure out why, why not, so what, and what else.

Our biggest challenge is that design thinking now stands alone as the singular mandatory course taught socratically in combination with experiential learning.[28] The macro-environment has not changed commensu-

[28] Experiential courses can be said to constitute standard fare in science and engineering curricula: computer coding classes and lab work, for example, constitute experiential courses.

rately. No connections exist between design thinking and more traditional courses taught by tenured faculty, whether in SEM or the other schools. While students can easily access activities such as hackathons, innovation competitions, and seminars and conferences on the theme of entrepreneurship, they do not have sustained guidance and mentorship to take forward what they have learned from design thinking. That is to say, our efforts to 'stimulate critical thinking and creativity' are quickly diluted during the course of their daily study and lab work.[29]

On a macro basis, nurturing innovation at a national level requires dedication from multiple domains and demands more input in 'software' than 'hardware.' Universities alone (let alone a handful of faculty) cannot make any sustained systemic changes. Apart from increasing industrial partnerships, a more coherent and interconnected network must be formed. For instance, wholesale curricular re-design from the elementary level to undergraduate (and even post-graduate level) must occur. Teachers must adapt teaching styles and change course design. In parallel, universities, communities, industry, government and non-government organizations must share a mission to form deeper meaningful partnerships to support innovation-driven learning settings, workplaces, and robust environments.

Design Thinking Is Really About Thinking

We have expressed the need for contextualizing the structure and curriculum of design thinking. At ShanghaiTech, this included factors such as students' learning habits, STEM majors, and life experiences (or lack thereof). It turns out that planting the innovation and entrepreneurship seed meant challenging students' thinking modalities and inspiring them to believe they could make a difference in society's future well-being by creating solutions to wicked problems (particularly social issues in China). Therefore, we have placed critical thinking at the core of our course. Critical thinking is not simply an isolated section at the beginning of the course. We constantly refer back to critical thinking not only in the formal design thinking portions of the course, but also to prompt student reflection on topics such as academic integrity, ethical implications of bioengineering, and social responsibility.

[29] SEM currently does not offer any majors or degree-granting programs.

We have witnessed an improvement in our students' critical thinking abilities, and a few students have told us that they consciously apply what they learned to their other studies and projects. Reflecting back on our journey of teaching and adapting the design thinking course, we feel confident the course acts as a gateway for students to approach problems with a critical mind while creating solutions by making unexpected connections. Design thinking is far from simply design for us. It is an intellectual trigger, urging learners to unlearn and relearn in response to the complexity of real-world issues.

The effort in China is a mirror for educational reform efforts around the world. The ultimate goal of innovation education (or any education) is really about stimulating students to think critically in uncertain environments and take action to create a better world. No singular course, curriculum, or technology can substitute for the hard thinking that must go into teaching our students how to think and behave in this way.[30]

Challenge of Cultural Change

In our view, simply allowing us to teach design thinking to STEM students at a new Chinese university signals a certain level of openness within the system, particularly with regard to the concept of critical thinking. Knowing that 'how' a course is taught weighs more than 'what' is taught, we do not underestimate the challenge of impacting deeper change. China's long history of exam-oriented education (as well as a corresponding school system and evaluation mode) poses formidable obstacles. Equally challenging in China is finding qualified instructors and interested tenured/tenure-track faculty.

At its root, however, critical thinking entails questioning authority, and a certain degree of freedom of thought. In the West, we equate these things with academic freedom and democracy, which in our view sets the foundation for creative thought and truly disruptive innovation. One might argue that most of China's innovation to date comes simply from the normal learning process that happens between developed and developing nations. While we agree with this observation, we believe it also undervalues China's success in growing its economy. At the same time, China is yet to produce what some might consider a 'true disruptor'—

[30] At some point, countries will also need to face the challenge of how we measure innovation education and innovation itself.

almost all of its current innovation can be categorized as business model innovation (or more uncharitably, copying and adapting), variations on existing products, or incremental innovation.

From our perspective, this leads to (at least) two critical open questions. *Can incremental innovation lead to genuine disruptive innovation? Can the requisite critical thinking necessary for innovation occur without the attendant levels of freedom of thought?* We believe China is searching for the answers to those questions. Unquestionably, China's leadership understands the dilemma they face in encouraging innovation: balancing the need for innovation and economic growth that requires loosening of control with maintaining its current political structure and control. This balancing act is at the crux of their desire to find a Chinese model of innovation. Can China take the lead in artificial intelligence, not simply in research, but in commercial application in the current intellectual environment? Do the right ingredients exist in Chinese universities? We do not have a clear answer to this question. Significant governance issues make it difficult to see a path forward. The university environment of fertile intellectual discussion, creation of knowledge, and disagreement that we recognize in Europe, Australia, and the United States does not exist quite yet in China. Yet perhaps enough of the requisite pieces will fall into place to generate some version that is true to the Silicon Valley model of "just good enough".

Conclusion

China faces a great many challenges domestically magnified by the oncoming 4IR. Finding a model to innovate is core to China's success. Successfully finding a model to innovate will be a good barometer for measuring China's efforts to find its own models in other domains. Will these efforts yield results that the nation can take pride in? Will China be able to cultivate smart talents to create smart systems for the human world at the age of 4IR? For China, its determination, its humility to learn from better examples, its long tradition of diligence and perseverance are its greatest advantages for driving innovation forward. It is still too early to say that a Chinese model of innovation has begun to emerge.

Pessimists about China predict a hard crash. Optimists predict the future belongs to China. We classify ourselves as realistic optimists: not sanguine about the challenges China faces, but not willing to bet against a country which has achieved an economic miracle never before witnessed

in human history. The world's future depends on a prosperous and peaceful China. With the right guidance, with human-centeredness at the core and where ethical and moral issues associated with the 4IR are carefully considered, as educators, we believe in our students and their potential to shape the future.

Appendix A: General Education Models

In most Chinese universities, each student enters the university with a major (which they selected when they took their college entrance examination) and their courses dictated by the relevant schools.

Compulsory Courses for Freshmen

Fudan University

Fudan's Generation Education Program classifies core courses into seven categories, namely Classics Literature and History, Philosophical Wisdom and Critical Thinking, Dialogue of Civilization and Global Perspectives, Social Research and Contemporary China, Scientific Exploration and Technological Innovation, Care for Environment and Life, Art and Aesthetic Experience.

Special Programs

Peking University and Tsinghua University

Beijing University founded the Yuanpei College in 2007 and each year the college carefully selects and enrolls a small number of undergraduate students. The students take general lessons at the college in their first year and they then select their major and take major courses in the faculties. A similar program was introduced at Tsinghua University in 2014 when the Xinya College was established.

Appendix B: The Desert Island Challenge

You are a group of strangers who have been cruising around the Indonesian Sea, enjoying all the luxuries that a top-class cruise liner has to offer.

Last night, a bad storm left your ship in pieces and your group is the only remaining survivor.

Table 5.1 List of items to choose from for the desert island challenge

Body-warming bag (foil)	*Set of 4 flares*	*Tin of beans*	*Pack of cigarettes*
Torch with batteries	Whistle	Box of matches	Set of keys
Large rope	Blunt knife	Mirror	Bottle of rum
Set of 3 small fishing hooks	500 ml bottle of water	Sleeping bag	Magazine
Basic first aid kit	Ballpoint pen	Mobile phone (not a satellite phone)	Tin cup

You are in a small lifeboat with five other people. There is very little room and you are only just managing to keep the water out. You have some things in a small rucksack that will help you to survive once you reach the desert island that you can see on the horizon.

However, you cannot take them all with you. You can carry five of the items from the rucksack and you have 25 minutes to decide (which includes transition time to your breakout area and back).

Your team must then explain your choices in 3 minutes to convince me that you made the right choice. I want to know which items you chose and the rationale for your team's choices.

Appendix C: Examples of Students' Projects

During the most recent summer term, students worked on projects with the grand theme of 'making old people happy.' We list two examples from this term illustrating the students' realization that simple design (rather than application of technologies such as VR) often provides superior solutions.

Eat Better

Insight: Most old people had dental problems and even those who wore dentures found it difficult to eat healthy yet hard food.

How Might We Question: How Might We help elders wearing dentures eat hard food?

Solution: Meat hammer and creative food knife.

Note: The group started with a number of common issues facing the elderly: Malnutrition; Aspirations; Social Contact; Empty-nester. At the

ideation stage, they came up with solutions which they subsequently divided into four broad categories:

1. new tools that change the texture of food;
2. new ways of processing food;
3. new methods to improve existing dentures which fit better;
4. ways of warning them not to eat the type of food that might hurt their teeth.

They measured their solutions on the feasibility and impact axis and selected four products. The students even created a visual demo and did a small-scale user test, after which they gained feedback and identified their final solution.

Towel Wringing Gadget

Insight: Old people are not willing to use high-tech products or do not care about high-tech problems. Arthritis, however, can be a big problem that affects old people's happiness in their daily life.

How Might We Question: How might we design a product to help senior citizens with arthritis problems (who are not willing to accept technology products) overcome inconvenience caused by arthritis?

Solution: Towel Wringing Gadget

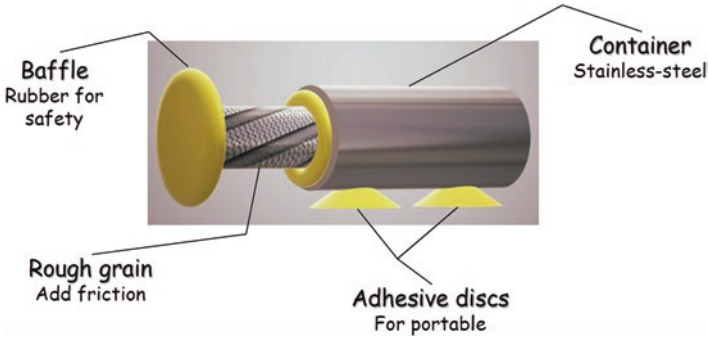

Fig. 5.1 Towel wringing gadget

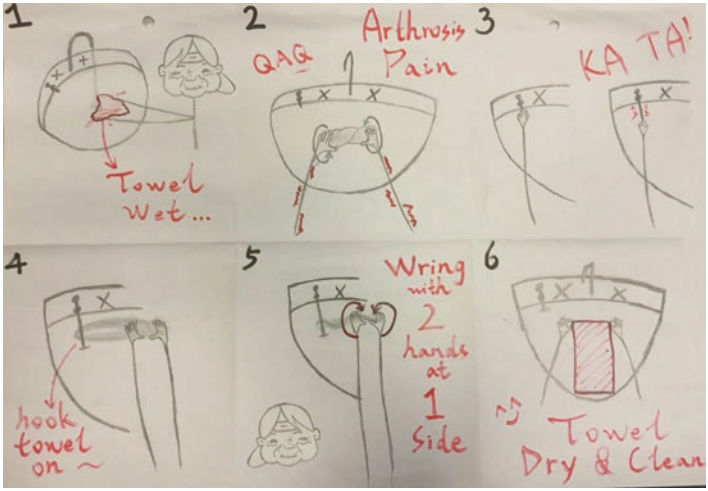

Fig. 5.2 Towel wringing gadget drawing

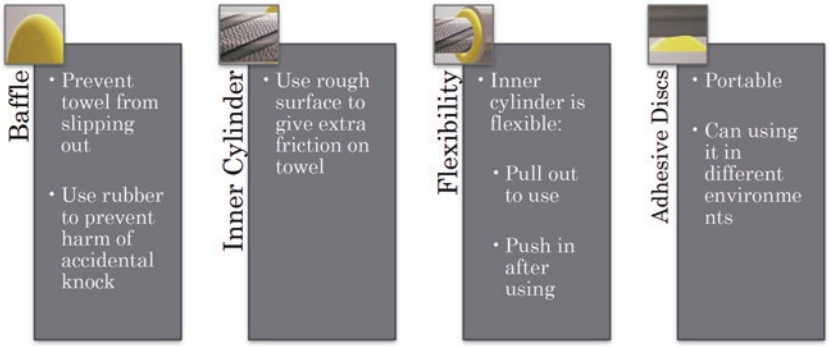

Fig. 5.3 Operation of towel wringing gadget

Here are two other examples from earlier terms when students had the total freedom to work on problems that they themselves identified. While the solutions of the following two projects do not win high marks in terms of their originality and creativity, they exemplify that students spent much effort and time in locating a wicked problem that they care.

Dress and Appearance of University Students

Problem: University students' clothing is closely linked with their self-esteem and confidence (and thus affect their job-hunting).

Insight: Guys do not have enough motivation nor knowledge when it comes to improving their appearances. They do not have any interactive and customized tools that offer them feedback about their clothes.

How Might We Question: How might we create effective ambience for male university students to discuss their clothes (with an aim to stimulate them to improve their appearance through helping them to better choose their outfits)?

Solution: A social application that provides a community where users can get rates and feedback on their clothes as well as professional advice and recommendations.

Food Waste Reduction in Restaurants

Problem: Food waste is a common problem and the cost for processing food waste is extremely high.

Insight: The situation of food waste in hotpot restaurants is more severe as it is not easy to take away unconsumed food.

How Might We Question: How might we reduce food waste in hotpot restaurants with lower cost?

Solution: A specially designed menu that matches customers' diverse needs (dietary and emotional) coupled with detachable tableware.

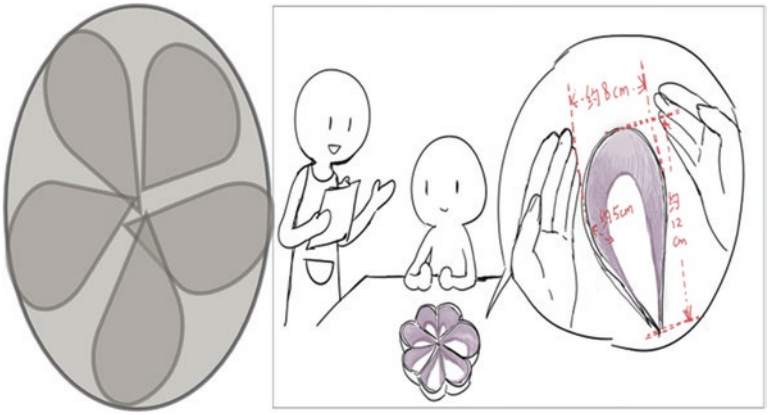

Fig. 5.4 Example of detachable tableware

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Check for updates

CHAPTER 6

Regenerative Development in Higher Education: Costa Rica's Perspective

Eduard Müller

Introduction: How Did We Get to Where We Are?

Our planet is in trouble: climate change, a consumer society that extracts more resources than what the planet can provide, a broken economic model, combine with politics gone wrong. We also have incredible power in communication technology, especially through social media. We have enormous capacity for data analysis, trending rapidly to data analytics and artificial intelligence (AI). However, we are not able to transform all this information and knowledge into wisdom, yet.

According to Wikipedia, "Wisdom or sapience is the ability to think and act using knowledge, experience, understanding, common sense, and insight. There appears to be consensus that wisdom is associated with attributes such as compassion, experiential self-knowledge, non-attachment and virtues such as ethics and benevolence."[1]

The first sentence shows how far away we are from our true goal. We are officially undergoing the sixth planetary extinction, we have moved

[1] "Wisdom," Wikipedia, January 15, 2018, https://en.wikipedia.org/wiki/Wisdom.

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from the Holocene to the Anthropocene. This is the best scientifically documented planetary extinction—we have all the science and know with great precision what we are doing wrong. The second sentence relies on intangibles which cannot be accurately measured and thus not very popular in traditional academic approaches. The acceleration of time, with changes happening so fast, has contributed to immediacy and ephemerality. Taking time to step outside of the daily rush and look at the broader perspective, beyond our immediate needs, has been downgraded in response to the urgency for action, and the competitiveness of human enterprise. Determining what went wrong at this point in history is probably impossible, especially since there are so many factors involved. This is precisely what brings me to my main argument: The reductionist approach to Western education is a key challenge!

Reductionist Versus Holistic Approaches

We can trace the origins of reductionist approach back to Socrates and Plato and the Socratic Dialogues which proposed that research should clearly identify one question, the Hypothesis, and focus on finding one answer. We could also invoke Aristotle with his 'Prior Analytics' or Descartes, whose scientific philosophy was based on the assumption that the material and spiritual realms of human existence were disconnected and, being the human mind separate from nature, enabled humans to control nature. We could also argue that it started with Isaac Newton, who was convinced that the universe was made up of bodies that behaved uniformly, following the laws of motion where interactions are limited to simple relationships related to the forces exerted between the bodies.

Whatever argument we choose, the reality is that the reductionist approach evolved based on the fact that a system could be understood by studying the individual components, which were literally, in some cases, dissected to death. This led to the establishment of disciplines, faculties and departments at our universities and to an ever-ongoing spree of specialization. This also affected the institutional frameworks, with separate entities being established to deal with environment, agriculture, economics, culture and so on. The belief prevailed that the best science is the one that describes the smallest detail and is published in the corresponding most prestigious peer-reviewed journal. The idea that interactions between components of a system can be more relevant than the components themselves, and that the end sum is greater than the sum of the individual components, was ignored. The thought that there can be something even

greater that transcends systems such as consciousness was actively opposed and still remains mostly controversial in science.

Systems Thinking

A little less than 100 years ago, Ludwig von Bertalanffy started what we know today as systems thinking or systems theory.[2] The concept of *Ganzheitlichkeit*, from *Ganz*—which stands for healthy, not hurt and complete or integral—can be translated to holism and according to Thomas Diesner is the consideration of a matter in the systemic integrity of all parts, as well as in all their properties and relationships.[3] This has since influenced how higher education approaches system thinking. In the early 1980s, Robert Hart started working on applying Howard T. Odum's approaches in ecological systems to farms in Honduras and Costa Rica, using interdisciplinary approaches to learn from and optimize the interactions that take place within a productive system. Flows between the agroecosystems and between the farm and its surroundings were measured in energy units, biomass, labor or money.[4] Decades later, attempts at defining systems thinking are still taking place[5] while the great majority of our institutions, universities and curricula are still mostly disciplinary.

Complex problems such as global change, climate change or poverty require complex solutions. Individual disciplines cannot understand these complex issues and have proven completely unsatisfactory in providing solutions. All three are increasing after decades of academic and technical work. While trying to find better solutions, we have transitioned through multidisciplinary and interdisciplinary approaches, without great success in changing our development path. One of the difficulties is appropriate dialogue; often specialists from different disciplines lack a common language for even the most basic communication and understanding. Scientists, generally, have great difficulty simplifying their vocabulary to communicate with other stakeholders, especially groups like politicians or local communities.

[2] Thomas Diesner, Die Allgemeine Systemtheorie bei Ludwig von Bertalanffy. Eine Begründung interdisziplinärer Wissenschaftspraxis (Berlin: Logos Verlag, 2015).

[3] Diesner, Die Allgemeine Systemtheorie bei Ludwig von Bertalanffy. Eine Begründung interdisziplinärer Wissenschaftspraxis.

[4] Eduard Müller, Cash-crop with animal production systems: coffee, sugarcane with dual-purpose cattle (Turrialba: CATIE, 1982).

[5] Ross D. Arnold and Jon P. Wade, "A Definition of Systems Thinking: A Systems Approach," *Procedia Computer Science* 44, (2015): 669–678.

Holistic Approaches

In order to advance with holistic approaches, we need to transcend the individual disciplines. Transdisciplinarity gives us the possibility for developing holistic approaches and proves that the true interaction of different disciplines can have a result that is greater than the sum of the different disciplines. It therefore transcends each discipline and requires viewing our subject matter from different perspectives and even different time frames. Nicolescu describes it as a unity of knowledge beyond disciplines.[6] The caveat is that in order to be successful in working with transdisciplinarity, participating individuals need to understand the different disciplines and have the skills to promote and mediate dialogue to assure full integration across the board.

This is where we hit one of the most important obstacles in modern education. Even if a university decides to take on the task of incorporating holism, getting adequate teachers is an enormous challenge, since most of them have been educated under reductionism. Many academics that are interested in holistic approaches are viewed by their peers as "light" or superficial while holistic academic development is also hampered by the ranking methods used in most of the world. Transdisciplinary journals are scarce and are not considered to be among the most prestigious, thus the academic points given to holistic research are not an incentive. Holistic approaches often require the integration of intangible aspects, difficult to process with statistics and subjective analysis is not considered scientific by many. The knowledge dialogue, well known in Latin America as *diálogo de saberes*—the conversation between conventional science and local or indigenous knowledge—is a fundamental part of transdisciplinarity but has been historically regarded as non-scientific and it is not until recent years that it is gaining importance, due to the difficulty of solving complex problems at the local level.

Higher Education in Costa Rica: University for International Cooperation's (UCI) Experience

In Costa Rica, higher education is highly regulated by the Ministry of Education, resulting in antiquated rigid rules that act as heavy anchors to the evolution of education. Most people making decisions about universities,

[6] Nicolescu, Manifesto of Transdisciplinarity.

programs, curricula and even course contents are not academics and have been bureaucrats for decades. Professional activity is regulated by outdated laws that do not allow the evolution of new professions.

At UCI, we have had degree programs not approved by the ministry because the graduates did not have a professional association under which to affiliate themselves. One good example is the Bachelor's degree in Protected Area Management, a pioneer program launched two decades ago. The ministry at first did not approve the program because the professional association for biologists said it was administration and not biology, while the professional association of business said it was too biologic and not administrative. It took years of persuasion to finally get the program approved.

In order to reach out to students in the most remote places with high-quality programs, at UCI we started with distance learning using the internet in the mid-1990s but it took a decade convincing the ministry that learning in a non-face-to-face environment was possible. One of the major questions was *how do you assure that the person on the other side is the person who is studying and not someone else helping them out?* Other questions dealt with the lack of human contact which is vital to learning or the need for group work that could not be satisfied through communication technology. Today, many of these issues have slowly faded away but there is still a long road ahead. For example, we are still required to have a hard copy of all literature used in our online programs in a physical library (actually a book museum), even if a student will never step into our building. In Costa Rica and most Latin American countries, in order for teachers to be approved and officially allowed to teach in a degree program, they have to get their degrees recognized by the ministry, a process which can take months or even years. Having international teachers from all over the world is a plus that the majority of face-to-face programs cannot afford. After more than two decades of experience, we know that the learning experience in a vast array of fields can be greater through e-learning. The possibility of having students from ten or more countries interacting, doing group work, comparing realities, bringing in cultural aspects and real-time discussions of different national realities has proven to considerably enrich the learning process.

When regulating and managing online learning, the government and many universities still focus on technology, which is also a misguided practice and is the reason why some online programs are unsuccessful. Technology definitely helps but above all, learning methodologies—where

we have an ever-growing diversity to choose from—have to be used intelligently. Today, a great learning experience can be brought to a group of students in real time using applications like WhatsApp. In Costa Rica, all academic programs have to be authorized by the Ministry of Education; a process which may take well over a year or two. For the evaluation of these programs, authorities require, for example, that all courses be uploaded to the virtual campus before submitting the program for approval. This is clear proof that these authorities have no clue about education. By the time the program is approved, these course contents will be outdated and even the software version will probably be obsolete. The fact that a curriculum, the course contents, bibliography and even the teachers have to be approved by a central authority before being offered to students will soon make higher education obsolete and internationally based programs will wipe out local universities.

A problem that many universities in the region still face is the focus on knowledge. Students frequently continue to be exposed to hours of effort to acquire information and knowledge. A teacher, many times highly considered for being owner of knowledge, evaluates his or her students by how much of that knowledge is retained. Grading is done through exams based on mere repetition of memorized stuff. Today, information and knowledge are being produced at rates thousand times greater than the past, making it impossible for any human being to be up to date. Google and other search engines can give us, within seconds, all the information that we require. Soon AI will make the processing of this information more effective than the human brain, which cannot do data mining and analytics using huge databases in milliseconds. With change happening so fast, it is more relevant for students to be able to find the necessary information and knowledge, than try storing it in their brain. Acquired knowledge can become obsolete before it can be used. Finding a balance on what is the minimum knowledge a student needs to be able to correctly sort out the necessary information in a self-learning or flipped classroom process is not simple and will vary from individual to individual. Nevertheless, in the near future, knowledge acquisition will probably happen mostly outside the classroom.

The concept of skill-based learning was introduced into universities by the business sector that wanted professionals that could actually get things done. We can define skills as "the ability to do something that comes from training, experience, or practice"[7] or "the learned ability to bring about

[7] "Merriam-Webster Dictionary Online," Merriam-Webster Dictionary, Accessed August 22, 2017, https://www.merriam-webster.com.

predetermined results with maximum certainty, often with the minimum outlay of time or energy or both."[8] We have seen a shift over the last years in the importance of 'hard skills'—"the capabilities required for specific occupations usually related to professional knowledge, tools, or techniques that allow us to work within our profession"—toward a greater importance of 'soft skills' (also called 'people skills')—"the complete collection of our social, communication, and self-management behaviors and are vital for professional success."[9] Business usually prefers professionals with excellent soft skills who can learn what they need to know on the job. We must be aware that developing soft skills can be more difficult than learning the hard ones.

The concept of competence or competency has added another level of complexity.[10] In many places, competence is limited to skills and knowledge. In most of Latin America it reflects the concept of "good performance in diverse, authentic contexts based on integration and activation of knowledge, rules and standards, techniques, procedures, abilities and skills, *attitudes* and *values* (emphasis added)."[11] At UCI we are trying to get another layer on the top, passion, which we believe will give professionals the most value in designing their careers and life, by providing powerful energy to pursue even the most difficult challenges, which will be very necessary in the years ahead.

Education into the Future

It is already clear that higher education will change significantly in the near future. Many emerging learning platforms such as Singularity University, Udemy, Udacity, EdX, Coursera and many more are competing with traditional universities by offering flexible online learning possibilities that are allowing students to individually design their careers according to their specific demands. This represents one big challenge to many universities that will have to adapt or perish. On the other hand, global and climate changes are creating new challenges that are not being currently addressed

[8] Barbara Knapp, *Skill in Sport: The attainment of proficiency* (London: Routledge & Kegan Paul, 1963), 4.

[9] Eduard Müller et al., "Capacity Development," In *Protected Area Governance and Management*, eds. Graeme Worboys et al. (Canberra: ANU Press, 2015), 251–291.

[10] For more on competence, see Müller et al., "Capacity Development."

[11] Aurelio V. Sanchez and Manuel P. Ruiz, eds. *Competence-based learning* (Bilbao: University of Deusto, 2008), 29.

with effective holistic approaches. Educating people to respond to these challenges opens new opportunities.

Challenge 1: Disruption

Throughout the world, a rapid shift has started on how we learn. We experienced the birth of the MOOCs at the start of this decade and now see a rapid migration to micro-courses, co-creation platforms, design thinking and many others, which are greatly potentiated by emerging and exponential technology. As Ray Kurzweil, futurist and co-founder and chancellor of Singularity University, states: "We're in an era where we can make ourselves smarter with machines, not just with access to information at our fingertips through mobile devices, but we're on the cusp of being able to reprogram our outdated human software DNA."[12] This will probably be the definite challenge universities will be facing in the next few years and will probably define which ones survive. According to Ahmad Hasnah of Hamad bin Khalifa University "Students in the future will take their education from many different providers, and the problem in higher education is that we work in institutions that are perfectly adapted for environments that no longer exist."[13]

As a report from the Center for American Progress states, "This emerging disruptive innovation also presents an opportunity to rethink many of the age-old assumptions about higher education—its processes, where it happens, and what its goals are—and to use the disruptive start-up organizations to create institutions that operate very differently and more appropriately to address the country's challenges."[14] This report gives several recommendations to policymakers:

1. "eliminate barriers that block disruptive innovations and partner with the innovators to provide better educational opportunities";
2. "remove barriers that judge institutions based on their inputs such as seat time, credit hours, and student-faculty ratios";

[12] "Singularity University," Singularity University, August 9, 2016, https://su.org/about/press-room/press-releases/singularity-university-addresses-the-worlds-greatest-challenges-at-su-global-summit/.

[13] Paul Rigg, "University World News," October 31, 2014, http://www.universityworldnews.com/article.php?story=20141030125107100.

[14] Clayton M. Christensen et al., Disrupting College, How Disruptive Innovation Can Deliver Quality and Affordability to Postsecondary Education (Washington, D.C.: Center for American Progress, 2011), 4.

3. "not focus on degree attainment as the sole measure of success";
4. "fund higher education with the aim of increasing quality and decreasing cost";
5. "recognize the continued importance of research institutions."[15]

We live in a rapidly changing world where most of the in-demand occupations today did not exist five or ten years ago, where children born today will never learn how to drive a car or may not even own one, where the largest companies such as Uber, Expedia, Trip Advisor or Airbnb do not have fixed assets. AI and robotics have gone beyond manufacturing lanes. It is easy to understand why these will displace jobs at call centers (AI can already predict urgency of the call before it is answered), supermarkets (Tally—fully autonomous system for auditing shelves for out-of-stock items, low stock items, misplaced items and pricing errors), construction (brick-laying robots—Haradian X, 3D printed buildings), remote 3D printing of spare parts, medicine (IBM's Watson image interpretation and database analytics for treatment determination), law (data analytics, jurisprudence, legal document reviews). According to the World Economic Forum, by 2020, over 7 million jobs will have been lost due to disruptive labor market changes while 2 million new jobs will have been created, mainly in data analysis, commercializing, energy and media, entertainment and information.[16]

Challenge 2: Education for the Future, Beyond Sustainable Development

As an end result of all the aspects discussed above, higher education is facing one or more turning points and will have to adapt rather rapidly in order to survive, but even if it can adapt to the above challenges, will it be enough to help save humanity? What are the most important problems humanity is facing today? How can we truly address them? Will the technological advances be sufficient to revert planetary degradation? What else will higher education have to include to recover or maintain conditions for human livelihoods? These key questions highlight the importance of a new paradigm for development.

[15] Clayton M. Christensen et al., *Disrupting College*, 4–5.

[16] World Economic Forum, *The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution* (Geneva: World Economic Forum, 2016), http://www3.weforum.org/docs/WEF_Future_of_Jobs.pdf.

We have promoted degenerative development with massive resource extraction. If we look at the relation between the ecological footprint and biocapacity, we have clearly surpassed Earth's capacity to satisfy our current consumption; today we require the equivalent of 1.7 planets to provide the resources used and to absorb the waste produced. What we consume in one year takes Earth 18 months to regenerate.[17] In this destructive pathway, it seems that humans have forgotten that the natural world is what makes life possible, including ours. We need nature, nature does not need us!

At UCI we are convinced that higher education must go beyond the technological developments discussed under challenge 1. We need to clearly identify the main factors responsible for the collapse of our planet and of civilization as a whole. These need to be addressed with the highest priority, expertise and resources. At the same time, these challenges represent unlimited opportunities for new jobs that will provide great satisfaction in making a better world for all people. We cannot solve the mess we are in by using the same mindset and methods that have gotten us here. We need to urgently measure development with indicators other than those that have been used for decades. Using Gross Internal Product to measure progress is perverse. Measuring success with revenue that does not contemplate the true cost of the resources consumed or destroyed is immoral. Exploitation of fellow human beings to bring products at ridiculous prices for those who can consume should not be tolerated. And above all, we must remember that we have not inherited the planet, we are borrowing it from our children, grandchildren and future generations.

To be able to answer the above key questions and define priorities for education and capacity development we use the planetary boundaries concept, which can be easily understood by most groups of people.

Planetary Boundaries

The planetary boundaries approach was developed in an attempt to define the 'safe operating space for humanity'—meaning the conditions required for humans to develop and thrive, based on the biophysical processes that regulate the stability of Earth's system.[18] We have already crossed four of

[17] "Global Footprint Network," Global Footprint Network, 2017, http://www.footprintnetwork.org/.

[18] Will Steffen et al., "Planetary boundaries: Guiding human development on a changing planet," *Science* 347, no. 6223 (2015): 1259855.

nine planetary boundaries and these are the loss of biosphere integrity (biodiversity loss), land system change, the biogeochemical flow and climate change. Of these, climate change and biosphere integrity have each the potential to drive the Earth system into a new state, which will not allow our civilization to thrive.

Loss of Biosphere Integrity

The importance of biodiversity loss has been recognized for a long time. In 2002, countries set a goal that by 2010 the loss would be halted. This did not happen so that year in Nagoya, Japan, at the Convention of Biological Diversity COP10, the ball was kicked forward for another decade and the 2011–2020 Strategic Plan to halt biodiversity loss was agreed upon. The plan consisted of 20 very clear targets (Aichi targets) which countries agreed to achieve. With less than three years to go, we are not even close to achieving this target. Biodiversity loss has escalated to unprecedented levels. Current extinction rates are about 1000 times above the background rates[19] and as mentioned earlier, we are now in the sixth planetary extinction.[20] One problem that is ignored by many is that ecosystems can only tolerate a certain loss of biodiversity before losing their capacity for supporting life on Earth, including humans and though we are not clear where these limits are, we are already seeing ecosystem collapses at a scale that has never been witnessed by humans before. Ocean warming, acidification and pollution are changing and killing the largest ecosystem on the planet. On land, biological diversity has fallen below the proposed planetary boundary in about 60% of the land surface of the planet where more than 70% of humans live.[21] Habitats continue to be degraded and by the time the 2020 date is reached we will have lost two-thirds of vertebrate populations.[22] According to the WWF,

[19] Stuart Pimm et al., "The biodiversity of species and their rates of extinction, distribution, and protection," *Science* 344, (2014): 1246752.

[20] Gerardo Ceballos et al., "Accelerated modern human–induced species losses: Entering the sixth mass extinction," *Science Advances* 1, no. 5 (2015): e1400253.

[21] Tim Newbold et al., "Has land use pushed terrestrial biodiversity beyond the planetary boundary? A Global assessment," *Science* 353, no. 6296 (2016): 288–291.

[22] WWF, Living Planet Report 2016. Risk and resilience in a new era (Gland, Switzerland: WWF International, 2016).

> To maintain nature in all of its many forms and functions and to create an equitable home for people on a finite planet, a basic understanding must inform development strategies, economic models, business models and lifestyle choices: we have only one planet and its natural capital is limited. A shared understanding of the link between humanity and nature could induce a profound change that will allow all life to thrive in the Anthropocene.[23]

Pollinators are declining rapidly affecting agricultural and natural systems, while pests and invasive species are causing unprecedented harm to food security. Reports keep piling up on the graveness of the situation and the dire implications for humans without triggering the action that is needed. We are still putting economic gain above future life.

Biogeochemical Flows

Excessive use of fertilizers (nitrogen and phosphorus) has led to the crossing of another planetary boundary.[24] In spite of the lack of media coverage, disturbances to the nitrogen cycle are greater than those of the carbon cycle.[25] Between 30% and 80% of anthropogenic nitrogen used in agriculture leaks into the environment harming soil, ecosystems and human health while contributing to changes in the global climate system.[26] Nitrous oxide is the third most important greenhouse gas[27] with a global warming potential almost 300 times that of CO_2.[28] Over the last decades, academic institutions and the petrochemical industry have misled the world to believe that we need 'agricultural packages' consisting of agro-

[23] WWF, Living Planet Report 2016.

[24] Steffen et al., "Planetary boundaries: Guiding human development on a changing planet."

[25] Scott Fields, "Global Nitrogen: Cycling out of Control," *Environmental Health Perspectives* 112, no. 10 (2004): A556-A563.

[26] Eric A. Davidson, "The contribution of manure and fertilizer nitrogen to atmospheric nitrous oxide since 1860," *Nature Geoscience* 2, (2009): 659–662; Daniel J. Sobota et al., "Cost of reactive nitrogen release from human activities to the environment in the United States," *Environmental Research Letters* 10, no. 2 (2015): 025006; Jules Pretty, "Agroecological Approaches to Agricultural Development," November 2006, https://openknowledge.worldbank.org/handle/10986/9044.

[27] IPCC, Climate Change 2014: Synthesis Report (Geneva: IPCC, 2014).

[28] "Understanding Global Warming Potentials," EPA, August 9, 2016, https://www.epa.gov/ghgemissions/understanding-global-warming-potentials.

chemicals, irrigation, high yielding varieties, genetically modified organism and mechanization to feed the world, while international reports show the contrary. The use of pesticides is backed by similar false affirmations; a recent report from the United Nations states: "There continues to be a general lack of awareness of the dangers posed by certain pesticides, a condition exacerbated by industry efforts to downplay the harm being done as well as complacent Governments that often make misleading assertions that existing legislation and regulatory frameworks provide sufficient protection."[29]

Land System Change

Humans have altered landscapes for millennia. Throughout history, these changes have had local consequences; some of them have caused the rise and fall of previous civilizations such as the case of the Maya's in Central America. Currently, the extent of degradation is having global effects. Land degradation increases greenhouse gases and also the risks associated with climate change. It is also a major driver for biodiversity loss. Humans have already degraded over 1.5 billion hectares of land, corresponding to 550 million in Asia Pacific, followed by Africa with 500 million and Latin America with 300 million.[30]

Soil degradation is mainly due to wrong agricultural practices that are still being taught at universities and promoted through ministries of agriculture. Today, corporate agriculture has surpassed subsistence agriculture in causing the degradation. Agricultural expansion has also increased significantly the demand for water, accounting for 70% of the water withdrawals for irrigation at global level, reaching more than 90% in least developed countries.[31] There is an urgent need to regenerate degraded land, establishing functional landscapes that allow ecosystems to keep on providing essential services vital for life support. Though complete

[29] United Nations, *Report of the Special Rapporteur on the right to food* (New York: United Nations, 2017), 22.

[30] "Tackling Land Degradation and Desertification," IFAD, 2002, https://www.ifad.org/topic/resource/tags/desertification/2085419.

[31] UNESCO, *The United Nations World Water Development Report 2016* (Perugia: UNESCO, 2016), http://unesdoc.unesco.org/images/0024/002440/244041e.pdf.

regeneration of ecosystems will require decades or centuries, and might never be possible, it is the best bet we have in fighting our largest challenges today.

Climate Change

Climate change, while not yet as exacerbated as biodiversity loss, is a very important planetary boundary that has already been crossed and is accelerating at unprecedented rates. We have reached record-breaking temperatures throughout the last two decades. A great paradox lies in the fact that the last time humans could breathe in a normal atmosphere was during the 2015 Paris meetings, when the planet surpassed the 400 ppm milestone permanently,[32] the highest value in millions of years. Scientists are affirming that critical tipping points have been crossed or are in the verge thereof; global warming is close to becoming irreversible. Climate change information clearly indicates the urgency for action to save our current civilization. What was once debatable doom and gloom information is now underpinned by the most rigorous scientific evidence. In February 2016 global temperature reached 1.35°C[33] which is very close to the 1.5°C mark that is supposed to be reached in 83 years, a clear reason for immediate action.

Climate change not only causes direct changes in most of Earth's systems but also fosters other anthropogenic processes ending with rapid deterioration of basic conditions for life, seriously compromising land, freshwater and oceanic ecosystems. Natural and productive ecosystems are becoming less resilient. Countries are losing more and more crops, and food shortages are affecting millions of people, especially the poor. Water supply is decreasing in many regions at alarming rates. We urgently need new approaches, policies and actions to create 'counter-tipping points' to balance human development with the natural world. Climate change adaptation and mitigation require that the root causes of global change be addressed and that we move from knowing to doing.

[32] Brian Kahn, "Earth's CO_2 Passes the 400 PPM Threshold – Maybe Permanently," Scientific American, September 27, 2016, https://www.scientificamerican.com/article/earth-s-co2-passes-the-400-ppm-threshold-maybe-permanently/.

[33] "GLOBAL Land-Ocean Temperature Index in 0.01 degrees Celsius base period: 1951–1980," NASA GISS, accessed January 21, 2017, https://data.giss.nasa.gov/gistemp/tabledata_v3/GLB.Ts+dSST.txt.

Why the Boundaries Have Been Exceeded: A Brief Analysis

It is clear that Earth's capacity to maintain life as we know it is seriously compromised. "We stand at a critical moment in Earth's history, a time when humanity must choose its future."[34] Global change is with us, its consequences also. From more simple problems as vanishing pollinators, plummeting fish stocks and plastic pollution to complex issues such as climate change and poverty, we have managed to push our planet into a different future. Currently, as mentioned above, we are not able to maintain our life supporting planetary services, putting our civilization, together with many other life forms, at risk of extinction.

Economic development has been the primary focus of development over the last century and probably the single most important cause of our current disastrous situation. The linear economic model imposed on us with the promise that ever-increasing economic growth and the globalization of markets would trickle down benefits to everyone has left hundreds of millions of people without access to the so-called development. John Fullerton states that "our latest scientific understanding tells us that, notwithstanding its many achievements, today's form of capitalism rests upon outdated reductionist thinking that is fundamentally at odds with both the finite boundaries of the biosphere and the laws of systemic health in an interconnected world."[35]

Our social structures throughout many countries are broken. Sumptuous consumption and apparent ignorance of the consequences of our daily actions on our future—excess food and overweight societies that coexist with simultaneous starvation—the reluctance to giving up individual rights in favor of community ones or even planetary survival and many other factors prove this. We have developed into egotistic people who think of our world as if we own it and have the right to use and abuse it in favor of our comfort. Much of the initial trend was set in the United States, making them the largest contributor to global change until a decade ago. The problem is that this was exported to most of the world, promoted by international policies, including those of multilateral finan-

[34] "The Earth Charter," Earth Charter Initiative, last updated 2016, http://earthcharter.org/discover/the-earth-charter/.

[35] Fullerton, Regenerative Capitalism: How universal principles and patterns will shape our new economy (Greenwich: Capital Institute, 2015), 34.

cial institutions. Today, our society puts individual rights above collective ones and does not understand the meaning of solidarity.

Initial blame for this consumerism falls upon the automobile, one of the worst decisions humanity has made. David Blanks states

> As a powerful symbol of modernity, the automobile represented individual freedom, mobility, and independence. The car also linked the profound economic changes (especially the rise of big business) to the pursuit of personal happiness through consumption. Increasingly, Americans defined a happy life by one that offered personal and immediate gratification, even if this meant rising debt and a loss of local community.[36]

Propaganda (dissemination of information—facts, arguments, rumors, half-truths or lies—to influence public opinion)[37] invented by Edward Bernays in the late 1920s was the basis to promote consumerism—a well-known example being linking women's equality to men through cigarette smoking.[38]

Culture is what [still] makes us different from one another (e.g. Chinese, Japanese, German or Costa Rican). It is what woke the interest in tourism, even before nature was appreciated. I consider culture to be the 'glue' of our societies. Nevertheless, culture is being whipped out at speeds even faster than nature. Mass media, social networks, fashion, stuff, all have contributed to creating uniformity throughout the planet. Family structures, community organization and care, solidarity and many other characteristics that were unique to countries or regions are vanishing, being substituted by brand names and the need to accumulate things that are designed and built with programmed obsolescence to increase sales through repeated purchasing. When people lose their culture or consider it less than other cultures, they lose self-esteem and start imitating other cultures to try to fit in.

Politics have gone wrong in many countries, even those with democratic tradition. Short-term thinking, benefits for just a few, corporations

[36] David Blank, "Rise of the Automobile," accessed August 25, 2017, http://teachinghistory.org/history-content/beyond-the-textbook/24073.

[37] Bruce L. Smith, "Propaganda," last updated April 18, 2017, https://www.britannica.com/topic/propaganda.

[38] Wendy Christensen, "Torches of Freedom: Women and Smoking Propaganda," February 27, 2012, https://thesocietypages.org/socimages/2012/02/27/torches-of-freedom-women-and-smoking-propaganda/.

controlling politicians, corruption, and many other wrongdoings are now common ground. What is called corruption in some countries is called lobbying in others—and is legal. However we look at it, buying a politician's favor is not correct, it is not moral. Youth is disappointed and does not want to get involved in politics. Democracies have turned into election events with almost no civil participation in between these.

Spirituality—detached from religious beliefs—has been left behind. The scientific approach, as we explained earlier, separated humans from nature and pushed our educational process toward physics. I consider spirituality to be the only true pathway that will allow us a paradigm shift of the magnitude and urgency required. A person's heart must be touched. We need deep consciousness of what we are doing, individually and collectively. Recognizing individual responsibility is essential and the starting point. Each and every one of us must begin to change. Individual responsibility has to be then collectivized to be able to reach the scale we need. Higher education needs to support this mindset if we are to effectively adapt to a world where the technologies of fourth industrial revolution (4IR) combine with the impacts of climate change.

Another constraint of modern science and its education is that it must be fact based; any spiritual or intangible component is traditionally not contemplated. I personally feel that without the spiritual component, advancement in solving our complex problems of today will be slow. When discussing this subject with university leaders, especially those from developed countries, I always get questioned on how to measure spirituality, and since I cannot measure it, why teach it? There are no current methods to effectively teach spirituality, but it can and must definitely be promoted among our students. Open discussions, mindfulness, living nature, experiencing real-life situations in the poorest or at-risk populations, getting out of our bubbles, seeing the world and understanding the true meaning of life will surely change the mindsets of the majority of students.

However, we have not been effective at educating for sustainable development. As mentioned before, complex issues cannot be addressed through the traditional disciplinary approaches. Over the last three decades, we have been discussing sustainable development, holding hundreds of conferences all over the world, first to agree on a definition and then on how to achieve it, with hundreds of beautiful booklets and reports printed. Yet, we are not even close to achieving or at least curbing rate of global destruction. In the early definitions, sustainable development was about leaving future generations similar conditions to the ones we inherited.

Now, it is about all present human beings, irrelevant of age, class or race, being able to make the change that will allow our civilization as a whole to have a future. By now, it will be a different future, but the more we wait to take action, the more people will be vulnerable, the more people will suffer and the whole foundation for our current civilization will be undermined.

Regenerative Development

In order to move forward and have livable conditions in the future, we must immediately stop degenerative development. A clear example is the environmental impact assessment that gives a company, government or any project the possibility to get approved as long as it minimizes environmental and social impacts. Under the conditions the planet is today, this is immoral, any project must have positive impacts in nature and society; economy cannot be placed on top of life-sustaining ecosystems and human well-being.

To revert our self-destructive pathway, we need to modify what we have been doing so far, moving to holistic approaches that optimize Earth's biocapacity (the planet's biologically productive land areas) while keeping our footprint within the planetary boundaries. This can only be achieved through true transdisciplinarity. Academic programs must also shift to intensive knowledge and data use incorporating local knowledge—adapting to climate change is very local, there are no recipes. Current dynamism also will require programs to be more prospective, looking into the future. Retrospective management based on yearly plans and end-of-year achievements will not suffice. They must adopt prospective or creative management which uses climate change and socio-economic future scenarios to deal with complexity and uncertainty in the development of plans and policies for climate change.[39]

Regenerative development will provide for the creation of thousands of new jobs, especially but not exclusively in developing countries. New professions will arise as new challenges appear. Great opportunities for knowledge and experience exchange will lead to innovative partnerships for co-creation of methods and processes.

[39] "Marieke Veeger," CCAFS-CGAIR, August 22, 2017, https://ccafs.cgiar.org/about/people/marieke-veeger#.WZyCaSiGM2w.

Regenerative development starts with a profound reform in our way of doing things, by holistically integrating six fundamental pillars, including

1. regeneration of functional landscapes, where we produce and conserve in a defined gradient of uses, maximizing biodiversity and ecosystem function to guarantee the provision of the basic ecosystem services to sustain life on Earth, including ours;
2. social strengthening by community organization, empowerment and development to allow local communities to recognize and reverse their negative behavioral patterns and enhance the positive ones to allow them to cope with adaptation to a changing planet, including climate change, and reduce sumptuous consumption patterns;
3. a new paradigm for economic development where people matter more than markets and money, measured according to the well-being of humans and all life forms, based on the circular principles of nature, where 'waste' is the input to another part of the system, nothing is disposable;
4. conservation and valuation of living culture which is the necessary bond for community life, where local knowledge, values and traditions are shared within family, friends and the community as a whole, giving meaning to these terms, where self-esteem is recovered and enhanced, allowing community proudness to facilitate collective action and the true achievement of a harmonious relation with all;
5. rethinking and redesigning current political structures so they reflect true participatory democracy and inclusiveness, without the influence of money and power and especially fostering long-term vision and actions that seek increased livelihoods and happiness and not only gross income;
6. fostering deep spiritual and value structures based on ethics, transparency and global well-being to allow humanity to live in peace with itself and planet Earth.

In practice, implementation of regenerative development requires a close participation of different experts from a diverse set of disciplines and at least one leader that has the competences to lead this team to work in a transdisciplinary manner. Basing the approach on a specific territory is key. The six main aspects to be contemplated can be looked upon as blankets that are laid one over the other. Our focus cannot be the individual blanket—it must look at the vertical interaction between them. Many different

methods can be integrated in the educational process. We have been most successful by applying the competence framework mentioned earlier.

All sectors of society have to act promptly to save life on our planet and reestablish a balance that will allow our civilization to thrive for centuries to come. The problem is that few actually know how to do this. In order to offer an immediate solution, we need to move to innovative educational programs to satisfy the need of highly qualified professionals to effectively and efficiently promote a new paradigm for development. The highly developed competences in managing projects together with the unique competences on regenerative development offer private and public sectors the manpower to address the urgent action that is needed to reverse the current situation and allow for future prosperity and human happiness.

Regenerative development is rapidly gaining global momentum and again UCI is a pioneer in this holistic approach. Graduates will have a higher ability to go far beyond other professionals, resulting in effective positive change within their organizations, by showing strong differentiation with positive impacts in the well-being of society and the environment, while increasing the economic benefits. Investing in this globally unique master's program will open numerous possibilities both for the professional as well as for their organizations, through the enhanced environmental and social responsibility, sensitivity and consciousness. The international exposure and experience bring along a whole other set of extraordinary competences.

Education for regenerative development faces many challenges. Developing competences for holistic approaches will be difficult. A good starting place is to un-learn many of the things that were taught to us. We need to develop a much stronger critical analysis of what is considered good for development. We also need to reevaluate how we do science and manage knowledge. The last sentence of the Earth Charter states: "Let ours be a time remembered for the awakening of a new reverence for life, the firm resolve to achieve sustainability, the quickening of the struggle for justice and peace, and the joyful celebration of life."[40] It is likely that the 4IR will enable an awakening of many kinds, one in which we reimagine our humanity. The ideas of regenerative development should be integrated into higher education curriculum and administration in order to ensure that the learning supports a sustainable future.

[40] Earth Charter Initiative, "The Earth Charter."

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CHAPTER 7

Singapore's Higher Education Systems in the Era of the Fourth Industrial Revolution: Preparing Lifelong Learners

Nancy W. Gleason

Introduction

Global society is changing because of the shifts in technological capacity. Higher education must change with it. Singapore is, once again, at the forefront of innovation in higher education. This chapter reports on research that details the large-scale government initiatives launched to develop an education system that is future ready. Singapore serves as a model to nations around the world wanting to prepare their workforce with ways of thinking and working that are in demand in the fourth industrial revolution (4IR).

Singapore's economic prosperity is closely linked to its successful education system. With a population of approximately five million people, outstanding development, good public health, and robust economic growth, the employment prospects for most of its citizens have been strong to date. However, McKinsey Global Institute data recently claimed

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that 44% of jobs in Singapore are automatable.[1] That represents a third of the workforce that will need to be upskilled and retrained in the near future. Singapore's education system has a reputation for preparing excellent STEM learners, where students learn to the test. This was useful in creating a workforce that crunches and manages numbers efficiently. Creative and critical thinking did not come from this sort of preparation, however. Now plans are under way to develop more holistic education systems that teach students *how* to learn, rather than *what* to learn in order to adjust and continue to have an education system that delivers what the economy needs.

Singapore has always been adaptive, and this is reflected in its approach to education. This chapter explains the current revisions of higher education in Singapore, which are designed to instill lifelong learning tendencies in the Singaporean population. Through the implementation of three ambitious government-led efforts, Singapore is altering the way it educates people. The three specific higher education developments reported upon here are the Smart Nation Singapore, SkillsFuture Singapore, and the establishment of several new higher education institutions. Through these initiatives Singapore is preparing for the future economy with remarkable ingenuity.

Impacts of 4IR on Global Society

Many current jobs are automatable; time will tell just how many and in what areas. Automation is the result of technological developments facilitated by advances in big data, cloud computing, and machine learning. Indeed, the processes under way are changing what it means to be human. How we work and live is changing because we now have access to massive amounts of data which can tell us new things and can enable machines to do new things. Some new jobs will come, but it is also true that we face a future in which there may be economic growth without job growth.

The so-called fourth industrial revolution involves cyber-physical systems (CPSs) taking over much of the work currently being done around the world. The mechanisms of that change are complex but acting swiftly. CPSs are at the heart of the changes many in the world are already experiencing.

[1] Lin Diaan-Yi, "What executives need to know about automation," February 2017, https://www.mckinsey.com/~/media/McKinsey/Locations/Asia/Singapore/Our%20insights/Automation%20DY/Automation%20DY.ashx.

CPSs are computer-based algorithms that work with physical processes in which embedded computers and networks monitor and control the physical processes of machines and artificial intelligence (AI) in a feedback loop whereby one informs the other. Today the technology is new but advancing very fast. Driving trucks, cars, or lawn mowers is no longer a human job. This has significant implications for economies all over the world. In the past, production has relied on machines to make core human labor more productive. We face a future in which humans may no longer be needed for production at all. Humans remain integral to 4IR; their creativity and ideas are driving the change. It is not as simple as machines taking over all routine and predictable tasks. Humans will work alongside robots, some claim as "cobots", and together they will amplify what is possible.

What 4IR Means for Higher Education

Traditional undergraduate education through information transfer is no longer a viable form of education to ensure employment and a career. In this context we must ask how do we prepare employable and responsible citizens in our tertiary education systems? Michael Peters has argued that education by itself will be insufficient to address problems of technological unemployment.[2] Others have emphasized the importance of liberal arts education as the ideal solution for creating future-ready graduates.[3]

Education through traditional institutions of higher education is still important, but their collaboration with industry and governments needs to be much more intense. Of course, universities still need freedom in their research, and many do not want their research agendas and curriculum dictated to them, but more communication is always a good thing. Financing from industry and government to upskill existing populations is also essential.

Currently, we understand that algorithms and CPS are doing routine and pattern-based work. This includes everything from making pizzas, to designing buildings, to reading radiology charts. The message from AI experts is that it is that which makes us human, our emotional intelligence and creativity, that will be in demand when this transition to automation is complete. Adaptive, flexible minds will be the most employable in the future, as they will have the cognitive agility to keep up with the fast-paced

[2] Peters, "Technological Unemployment: Educating for the Fourth Industrial Revolution," *Journal of Self-Governance and Management Economics* 5, no. 1 (2017): 28.

[3] Pericles Lewis and Katherine Rupp, "Liberal Education in Asia: Trends, Challenges, and Opportunities," *New Global Studies* 2015; 9(3): 245–266.

shifts in work place projects. *Accenture*, in a recent report, explains that a major trend of 4IR is the so-called liquid workforce, which turns away from older siloed models of work that were aligned to specific business functions.[4] Future work, instead, will be based on adaptive workforces organized around projects, supported by embedded training.[5] This new kind of employee needs a different kind of education in preparation.

Erik Brynjolfsson and Andrew McAfee argue that in order for people to remain "valuable knowledge workers," they must "work to improve the skills of ideation, large-frame pattern recognition, and complex communication."[6] Not everyone in the world can be a skilled worker in this context. The creative destruction of jobs will be disruptive, but new jobs will come in their place. As Joseph Aoun noted in his book *Robot-Proof: Higher Education in the Age of Artificial Intelligence*, thinking of creative ways to work is essential and universities are "ideal entrepreneurial ecosystems."[7]

Much research has been committed to understanding how people learn and what the best approaches are for teaching them to think creatively.[8] Students in different cultures and of different ages learn differently.[9] Furthermore, how educators themselves understand the concepts[10] of problem solving, critical thinking, and creativity is discipline specific and subjectively realized.[11] Evidence has shown that students learn more and recollection is greater when problem-based learning with an authentic

[4] Accenture, "Liquid Workforce: Building the workforce for today's digital demands" https://www.accenture.com/fr-fr/_acnmedia/PDF-2/Accenture-Liquid-Workforce-Technology-Vision-2016-france.pdf. Accessed March 12, 2017.

[5] Accenture, "People First."

[6] Brynjolfsson and McAfee, *The Second Machine Age* (New York: W. W. Norton, 2014), 12.

[7] Aoun, *Robot-Proof: Higher Education in the Age of Artificial Intelligence* (Cambridge: MIT Press, 2017), 69.

[8] Ambrose, Susan A., et al. *How Learning Works: 7 Research-based Principles for Smart Teaching*, (San Francisco, John Wiley & Sons, 2010).

[9] Siew Chee Choy, Daljeet Singh Sedhu, Yow Lin Liew, Mun Yee Lee, Audrey Malenee, and Norkhadirah Anuar, "Influence of Culture on Students' Awareness of How and Why They Learn," *Malaysian Journal of Learning and Instruction* 12, (2015): 49–67.

[10] UNESCO, *Preparing and Supporting Teachers in the Asia-Pacific to Meet the Challenges of Twenty-first Century Learning* (Paris: UNESCO, 2016). http://unesdoc.unesco.org/images/0024/002468/246852E.pdf.

[11] Siew Chee Choy and Phaik Kin Cheah, "Teacher Perceptions of Critical Thinking Among Students and Its Influence on Higher Education," *International Journal of Teaching and Learning in Higher Education*. 20, no. (2) (2008): 198–206.

outcome is the mode of education. Problem-based learning is student centered. A key characteristic is that students work in groups to solve open-ended challenges.[12] In particular, project-based learning has demonstrated itself to make students more motivated[13] and to encourage more effective engagement with discipline content.[14]

Building on the work of Carol Dewick's growth mindset,[15] psychologists Paul O'Keefe, E. Horberg, and Isabelle Plante have recently found that when students are interested, their attention narrows, yielding focused engagement.[16] Even better for work in the automation economy, this interest increases attention, eliciting exploratory engagement around the focused area.[17] This is the engagement that educators should be striving to elicit in their student learners. A large lecture theater with a single professor, in which information is transferred from the instructor to the 200–500 students seated in the room, is an outmoded approach to student learning. This pedagogy does not deliver the skills necessary for the automation economy as rote memorizing is not a skill needed in the era of 4IR: the machines will do that bit of the job for us. Such knowledge is not without value, but the content it is designed to deliver is only part of the puzzle of efficient and good work. Students need to learn new ways to manipulate content, over and over again. Problem-based learning and experiential learning are essential components to higher education pedagogy in the era

[12] Terry Barrett and Sarah Moore, eds, *New Approaches to Problem Based Learning* (New York: Routledge, 2010).

[13] Kay N. Drake and Deborah Long, "Rebecca's in the Dark: A Comparative Study of Problem-Based Learning and Direct Instruction/Experiential Learning in Two 4th-Grade Classrooms," *Journal of Elementary Science Education* 21, no. 1 (2009): 1–19; Mary Maloney, "Professional identity in early childhood care and education: perspectives of preschool and infant teachers," *Irish Educational Studies* 29, no. 2 (2010): 167–187.

[14] Michael M. Grant, "Getting a Grip on Project Based Learning: Theory, Cases, and Recommendations," *Meridan* 5, no.1 (2010): 1–17, retrieved from https://projects.ncsu.edu/project/meridian/win2002/514/project-based.pdf; John Larmer and John R. Mergendoller, "Seven Essentials for Project-Based Learning," *Giving Students Meaningful Work* 68, no. 1 (2010): 34–37; Robert J. Marzano, *The art and science of teaching: A comprehension framework for effective instruction* (Alexandria: Association for Supervision and Curriculum Development, 2007).

[15] Dweck, *Mindset* (New York: Randon House, 2006).

[16] O'Keefe, Horberg, and Plante, "The Multifaceted Role of Interest in Motivation and Engagement," in *The Science of Interest*, eds. Paul A. O'Keefe and Judith M. Harackiewicz (Cham: Springer, 2017), 49–67.

[17] O'Keefe, Horberg, and Plante, "The Multifaceted Role of Interest in Motivation and Engagement."

of 4IR.[18] Brynjolfsson and McAfee highlight the value of these self-organizing learning environments as well suited for what they call the second machine age, and understood more broadly to be the 4IR, and its employment demands.[19] Students need the habits of mind that such pedagogical approaches deliver in order to harness the benefits of 4IR.

Higher Education and 4IR Coalesce in Singapore

Singapore is embracing the automation economy, known as the "Future Economy" in the city-state. Since independence just 50 years ago, the nation has pulled itself out of poverty and forged an economic powerhouse out of an island just 720 square kilometers in size. Singapore is recognized as one of the four Asian Tigers, with economic growth as high as 7% between the 1960s and 1990s. Under the leadership of Mr. Lee Kuan Yew, education was prioritized under the Constitution's "Fundamental Liberties Article 16, Rights in respect to education."[20] This article proclaims that no discrimination against any citizen may be allowed on the grounds of religion, race, descent, or place of birth in order to withhold financial aid or pertaining to the payment of fees. Education is highly valued in Singapore, with students testing best in the world. In 2000, Singapore passed the Compulsory Education Act 2000, making national primary school a requirement for all Singaporean citizens born after 1996.[21] This again reflects Singapore's emphasis on advancement through educational merit. The Organization for Economic Co-operation and Development (OECD) provides a world-wide study through the Programme for International Assessment (PISA) which measures scholastic performance of 15-year-olds in mathematics, science, and reading. The OECD Report on PISA 2015 global results found that in science and reading Singapore has performed better than the OECD average and improved since 2006.[22] And that for mathematics, it is also

[18] Raja R. Hussain, Wan Hasmah Mamat, Norani Salleh, Rohaida Mohd Saat, and Tony Harland, "Problem-based learning in Asian universities," *Studies in Higher Education* 32, no. 6 (2007): 761–772.

[19] Brynjolfsson and McAfee, *The Second Machine Age*.

[20] "Rights in respect of education," Government of Singapore, accessed December 28, 2017, https://sso.agc.gov.sg/Act/CONS1963?ProvIds=pr16-#pr16-.

[21] "Compulsory Education," Ministry of Education Singapore, last updated November 17, 2017, https://www.moe.gov.sg/education/education-system/compulsory-education.

[22] OECD, "PISA 2015 key findings for Singapore," accessed December 27, 2017, http://www.oecd.org/countries/singapore/pisa-2015-singapore.htm.

better than the OECD average and has been stable in its ranking since 2006. In all three subject areas, Singapore has the maximum share of high performers.[23] For the PISA test, this means:

> Top-performing students in science can use abstract scientific ideas or concepts to explain unfamiliar and more complex phenomena and events. In mathematics, they are capable of advanced mathematical thinking and reasoning. In reading, top performers can retrieve information that requires the student to locate and organize several pieces of deeply embedded information from a text or graph.[24]

The OECD summary report also finds that the gap between boys and girls is very low in all three subjects (though it has increased since 2016 among boys and girls in science).[25] Yet there are challenges and contraversies associated with the system and the testing results. Rote memorization does not yield the necessary critical thinking skills when the students reach the job market. Furthermore, the population is now aging, which means innovations in higher education are only reaching those currently enrolled in tertiary education. But nonetheless, the test results demonstrate a significant commitment to education in Singapore, both structurally and socially.

There are deep cultural and economic motivations behind these strong testing results, and those conditions make Singapore primed to prepare a 4IR-ready population. Pak Tee Ng contributes important insights into the cultural and historical context within which Singapore seeks to win in the global talent wars.[26] Indeed, Singapore has sought to be an education hub as part of the global talent wars,[27] but also as an effort to address labor demands in the global economy. Research is demonstrating that Singapore has been winning the talent war with the incentives it creates for citizens and foreigners alike.[28] The challenge remains developing citizens with an

[23] OECD, "PISA 2015 key findings for Singapore."

[24] OECD, "PISA 2015 key findings for Singapore."

[25] OECD, "PISA 2015 key findings for Singapore."

[26] Ng, "Singapore's response to the global war for talent: Politics and education," *International Journal of Educational Development* 31, no. 3 (2011): 262–268.

[27] Ka Ho Mok, "Singapore's global education hub ambitions: University governance change and transnational higher education," *International Journal of Educational Management* 22, no. 6 (2008): 527–546.

[28] Balbir B. Bhasin and Kim Cheng Low, "The Fight for Global Talent: New Directions, New Competitors – a Case Study on Singapore," *Career Development International* 7, no. 2 (2002): 109–114.

entrepreneurial spirit able to reconcile the cultural adherence to reverence toward authority with the need for risk-taking creativity.[29]

Aside from cultural and political factors, the demographic evolution of Singapore is an important piece of the 4IR and higher education puzzle. The nation maintains a complex balance between citizens, residents, and non-residents that has implications for what types of education are needed in the future economy. Singapore was a nation of 5.61 million people in 2017. Of this 3.44 million are Singaporean citizens, 0.53 million are permanent residents (making 3.96 million residents), and 1.65 million non-residents which excludes tourists and short-term visitors.[30] The non-resident population employment passes can be used to support industries where talent is currently lacking in Singapore, be this in construction or in high-end computing.

Singapore's unemployment rate remains low in 2018 at around 3%. In terms of labor force, Singapore has another unique demographic circumstance.[31] One-third of Singapore's population comprises non-resident employment pass holders. This means that a large portion of the population is there on a special work permit basis that is justified by their skill set. The numbers of long-term residents can be tweaked based on the skills the government and industry need relative to what is already available among the Singaporean local population. In this way, the government has a lever it can pull to allow more jobs for newly skilled local Singaporeans. And while the tap cannot be turned off for highly skilled labor, the type of labor Singapore needs can be ascertained by turning the dial on what types of employment passes and for what skills these visas are issued.

The small nation also faces the challenge of an aging population. According to the Department of Statistics, Ministry of Trade & Industry, Singapore residents over the age of 65 made up 13% of the resident population in 2017, coupled with the median age of the resident population of 40.5 years. Both these numbers have been on the rise for over a decade

[29] Søren Christensen, "Higher Education and Entrepreneurial Citizenship in Singapore," *Learning and Teaching* 5, no. 3 (2012): 39–55.

[30] "Population Trends 2017," Department of Statistics Singapore, accessed December 18, 2017, http://www.singstat.gov.sg/docs/default-source/default-document-library/publications/publications_and_papers/population_and_population_structure/population2017.pdf.

[31] "Report of the Committee on the Future Economy," Ministry of Communications and Information Singapore, accessed December 28, 2017. https://www.gov.sg/~/media/cfe/downloads/mtis_full%20report.pdf.

now and are anticipated to continue upward.[32] This means that Singapore must invest in the education of its adult learners as well as prepare for a shrinking in its overall enrollments for institutes of higher education. In fact, Singapore's Ministry of Education (MOE) has announced that 14 primary schools and 6 secondary schools will merge in 2019 to adjust to the changing demographics.[33] Institutes of higher education are also experiencing lower enrolments as the demographic shifts reach them. These demographic trends mean that policies and higher education institutions need to support all ages, not just those in the 18–25-year-old range, in order to ensure enough of the right kinds of labor and jobs, and a continuing tax income for the government.

Singapore's 4IR Preparation

The *Report of the Committee on the Future Economy* came out in February 2017 outlining Singapore's economic strategies for 4IR preparation. This effort was a follow-up to the 2010 Economic Strategies Committee's work intended to take into consideration challenges of the automation economy.[34] The goal of the 2017 strategy is to ensure that Singapore experiences economic growth at 2–3% per year on average, stronger performance than most advanced economies to which Singapore compares itself. The report recognizes that Singaporeans must constantly retrain and upgrade their skills to stay relevant. The report lays out an innovative 7 Strategy Plan to alter society in preparation for the technological changes pending. Those that explicitly mention higher education and adult learning are:

1. Deepen and diversify our international connections
2. Acquire and utilize deep skills
3. Build strong digital capabilities[35]

Through these three efforts, Singapore is internationalizing its education and creating more experiential learning opportunities.

[32] Department of Statistics Singapore, "Population Trends 2017."

[33] Lianne Chia, "14 primary schools, 6 secondary schools to merge in 2019," Channel Newsasia, April 20, 2017, https://www.channelnewsasia.com/news/singapore/14-primary-schools-6-secondary-schools-to-merge-in-2019-8741660.

[34] "Report of the Economic Strategies Committee," Economic Strategies Committee, February 2010, http://www.mof.gov.sg/Portals/0/MOF%20For/Businesses/ESC%20Recommendations/ESC%20Full%20Report.pdf.

[35] Ministry of Communications and Information Singapore, "Report of the Committee on the Future Economy."

The first education strategy, "Deepening and Diversifying International Connections,"[36] is pursued in education through the Global Innovation Alliance (GIA) initiative intended to build new networks through which youth can facilitate innovation. The alliances are formed between Singapore's institutes of higher learning and major innovation hubs around the world to collaborate with overseas partners. An example of this already in place is the National University of Singapore's (NUS) Overseas Colleges, which has year-long or semester-long entrepreneurial start-up internship programs in Beijing, Israel, Lausanne, Munich, New York, Shanghai, Silicon Valley, Singapore, and Stockholm. A similar program, SkillsFuture Leadership Development Initiative (LDI), works to identify future corporate leaders and expose them to high-quality opportunities to acquire knowledge of regional markets.

The second education strategy relative to higher education and 4IR is to "Acquire and Utilize Deep Skills."[37] Deep skills include analytical and evaluative capacities combined with complex problem solving and effective team collaboration capabilities. This government policy calls for two significant shifts in social understandings of education. First, the report calls for a new approach which no longer expects students to seek the highest possible academic attainment as young as possible, but rather to learn and acquire new skills throughout their lives. Second, the report calls on Singaporeans to acquire deeper skills that create value. To survive these shifts and successfully transition to a digital economy, modularized programs are supported. This strategy is designed to help Singaporeans easily adapt to new labor demands and meet the needs of a transforming economic base, either in new jobs or to stay relevant in their current industries. According to this report, Nanyang Technical University (NTU), Singapore University of Social Sciences (SUSS),[38] and several of Singapore's polytechnic tertiary schools have launched more than 500 skills-based modular courses between 2015 and 2017.

There is an important cautionary note here. The ability and resilience to jump into many different skills-based training opportunities requires cognitive flexibility that does not come from this sort of vocational education.

[36] Ministry of Communications and Information Singapore, "Report of the Committee on the Future Economy."

[37] Ministry of Communications and Information Singapore, "Report of the Committee on the Future Economy."

[38] SUSS was formerly Singapore Institute of Management, and then UniSim. It changed its name to Singapore University of Social Sciences in December 2017. It is the sixth and final autonomous university in Singapore as of 2018.

Indeed, the skill-based modular approach could very well reinforce old models of education that do not develop the necessary skills for lifelong learning. It will be very important that these programs and, for future generations, the primary and secondary school education system, emphasize how to learn and not what to learn through pedagogy strategies noted earlier.

The third relevant strategy is to "Build Strong Digital Capabilities."[39] In response to the new industries emerging from digitization and the resulting big data production, this effort involves creating strong human capacity in data analytics and cybersecurity. Singapore intends to build joint laboratories between industry stakeholders and the government to train data scientists. Again, there will need to be creativity and interdisciplinary content woven into such efforts for them to be useful in the longer term. Interestingly, in March 2018, President Tan of the National Univeristy of Singapore (NUS) announced that computational thinking—namely statistics and programming—will be required of all NUS students regardless of their major.

Three Education-Focused Initiatives to Prepare for 4IR in Singapore

Singapore's higher education profile has shifted to reflect these realities in the past ten years. Attainment among Singaporeans of some form of higher education is up significantly. In 2016 over 52% of the resident population aged 25 and above has at least post-secondary qualifications, which is an increase from 36.7% in 2006.[40] The proportion of university graduates increased by 9.5% between 2006 and 2016, rising from 19.6% to 29.1%.[41] The proportion of residents receiving diplomas and professional qualifications increased by 3.9% over the same ten-year period.[42] Noting a change in demographic emphasis, data show that younger people are now more inclined to complete university education, with 54.3% of 25–34-year-olds graduating from university in 2016.[43] In the slightly older age bracket over the ten years between 2006 and 2016, 21.7% of those aged 35–44 years completed a diploma or professional

[39] Ministry of Communications and Information Singapore, "Report of the Committee on the Future Economy."

[40] Department of Statistics Singapore, "Population Trends 2017."

[41] Department of Statistics Singapore, "Population Trends 2017."

[42] Department of Statistics Singapore, "Population Trends 2017."

[43] Department of Statistics Singapore, "Population Trends 2017."

qualification[44] reflecting an investment in lifelong learning by the older learners. Part of the reasons these numbers have been able to rise is because MOE has established new and specialized institutes of higher education to create more options for Singaporeans and international students alike, this includes recently created of Singapire University of Technology and Design, the reconfiguration and autonomy of Singapore University of Social Sciences, Duke-NUS Medical School, and Yale-NUS College. Table 7.1 illustrates the intensive growth in this higher education sector in Singapore. As part of an effort to instill more diversity and autonomy in the local university system, many new institutions of higher education have been built in Singapore.[45]

One such initiative, within which Singapore's MOE has invested substantial financial resources, is Yale-NUS College. A collaboration that began in 2011 between Yale University and NUS resulted in the first liberal arts college in Singapore and one of the first in Asia. Yale faculty, together with experts from around the world, designed a unique curriculum linked with a distinctive pedagogical approach. The first cohort of students began studying at Yale-NUS College in August 2013.

The unique features of the College include an interdisciplinary international common curriculum, team-based teaching in the common curriculum, small class sizes which are capped at 18 students, extremely diverse student body, and a required four-year residential experience. The residential experience allows the learning to take place outside the classroom, which is important to the development of lifelong learning skills and is practiced elsewhere in Singapore to varying degrees.[46] These efforts are combined with experiential learning opportunities for all students and a robust study-abroad program. As noted above these are the sorts of self-organizing learning environments that foster the needed knowledge workers for the 4IR.

Yale-NUS students hail from over 50 countries, and ~50% of the student body is comprised of Singaporeans from diverse backgrounds themselves. The curriculum and faculty therefore must be culturally attuned, and training in this area is a consistent effort of the administration. The College's 14 majors and 5 double-degree programs are taught through blended disciplines and organized across three divisions of sciences, social sciences, and

[44] Department of Statistics Singapore, "Population Trends 2017."

[45] Søren Christensen, "Higher Education and Entrepreneurial Citizenship in Singapore," 42.

[46] Karen. K. Inkelas, "Good practices of living-learning programmes," *Asian Journal of the Scholarship Learning* 6, no. 1 (2016): 64–76.

Table 7.1 Singapore's growing higher education sector

Year established	*Institution of higher education*	*Academic focus*
August 1980	National University of Singapore (NUS) formally established by combining several pre-existing institutions with nearly 80 years of operational history on the island	16 different faculties covering engineering, social sciences, business, law, and many others. Undergraduate and graduate programs
July 1991	Nanyang Technological University (NTU) opened	Engineering, sciences, business, liberal arts, and medicine. Undergraduate and graduate
July 2000	Singapore Management University (SMU) established	Broad-based education with emphasis on business and management
September 2009	Duke-NUS Graduate Medical School	Medical school. Graduate-level only
May 2009	New LaSalle College of the Arts campus is officially opened	Contemporary arts and design
2009	Singapore Institute of Technology (SIT)	Applied degree programs in engineering, chemical engineering, Infocomm technology, health, and social sciences
May 2012	Singapore University of Technology and Design inaugurated	"Technology-intensive design education and research"
August 2014	Yale-NUS College	Undergraduate Liberal Arts and Sciences
August 2014	[Singapore Institute of Management/UniSim] renamed Singapore University of Social Sciences (SUSS) in 2017	Practice oriented for working professionals and adult learners in accounting, marketing, finance, HR management

Ho Yuen-Ping, Annette Singh and Poh-Kam Wong, "National University of Singapore," in *The Development of University-Based Entrepreneurship Ecosystems*, eds. Michael L. Fetters, Patricia G. Greene, Mark P. Rice, and John S. Butler (Cheltenham: Edward Elgar Publishing, 2010); "Our History," Nanyang Technological University, accessed December 28, 2017, http://www.ntu.edu.sg/AboutNTU/CorporateInfo/Pages/OurHistory.aspx; "History," Singapore Management University, accessed December 28, 2017, https://www.smu.edu.sg/about/history; "The Duke-NUS Story," Duke-NUS Medical School, accessed December 29, 2017, https://www.duke-nus.edu.sg/about/duke-nus-story; "History & Milestones," Laselle, accessed December 28, 2017, http://www.lasalle.edu.sg/about/history-milestones/; "Local Diplomas," Singapore Institute of Technology, accessed December 28, 2017, https://www.singaporetech.edu.sg/local-diplomas; "President Tony Tan officiates at celebrations at the Inauguration Ceremony of SUTD," Singapore University of Technology and Design, May 7, 2012, https://sutd.edu.sg/About-Us/News-and-Events/Press-Releases/2012/5/President-Tony-Tan-officiates-at-celebrations-at-t; "Milestones," Yale-NUS College, accessed December 28, 2017. https://www.yale-nus.edu.sg/about/milestones/; "SIM University to start Full-time Programmes in 2014 and to set up Third Law School in Singapore," Singapore University of Social Sciences, October 16, 2013, http://www.unisim.edu.sg/Happenings/Latest-Highlights/Pages/H2013_16Oct.aspx

humanities. Admission to the school is needs blind, holistic, and extremely competitive. All 105 full-time tenure-track faculty members at the College are expected to maintain both research and teaching excellence, publish in top-tier journals, and present at impactful conferences. The goal of all these efforts is to prepare the best minds to live a positively impactful life. Singapore has enabled the development of this liberal arts school as one of several strategic initiatives to develop 4IR-ready graduates for the economy.

The distinctive pedagogy involves close interactions between faculty and students both inside and outside the classroom. This is something that is relatively new to Singapore's higher education landscape. Teaching at Yale-NUS is learner centered and problem based[47] with very few lectures. Seminars last 1.5–3 hours in order to elicit deep discussion. Experiential learning and international experience are integral to the learning experience, which is consistent with Singapore's desire to internationalize its citizens. Through the College's Centre for International and Professional Experience (CIPE), experiential learning opportunities are mandatory for the entire first-year class. For example, one group of 18 students traveled to South Africa with a psychology professor and an international relations professor to study the psychology of racism with a close review of apartheid. Faculty-designed and faculty-led experiential learning trips—known as Learning Across Boundaries (LABs)—are interdisciplinary and are designed to get students into the field to apply the concepts, theories, and questions developed in the College's common curriculum.

The majors also provide depth in a given field but typically with an interdisciplinary focus. For example, the Mathematics and Computational Science (MCS) major offers students a unique opportunity to go beyond frontiers of traditional mathematics education. As the major's website explains, "We encourage students to participate actively in these flourishing developments. Displaying keen interest in this discipline, our students have embarked on projects to design robots, launch software start-ups, analyse big data networks, develop data visualisation tools, and philosophise on randomness and chaos."[48] Students have access to research attachments in cryptography, hypercube coloring, modeling, and simulation. These experiences are necessary for developing skills in ideation whereby students learn to ask questions about what they see and how concepts are applied. The courses students can take range from number

[47] Hussain, Mamat, Salleh, Saat, and Harland, "Problem-based learning in Asian universities."

[48] "Why MCS?," Yale-NUS College, accessed December 28, 2017, https://mcs.yale-nus.edu.sg/programme/why-mcs/.

theory to theoretical computer science, to operating systems, to statistical inference, and to statistical computing. Students in this program forge their own pathways. There is no single ascribed understanding of MCS. The flexibility and ingenuity of this major, coupled with the exceptional faculty and student capacity, make this a unique spot within Singapore's higher education landscape ideal for the 4IR context. Graduates of this programme will have the necessary cogntitive flexibility and interdisciplinary understanding to tackle complex global challenges.

The Yale-NUS College example is very different from the goals of developing deep skills through focused, performance-based learning. The development of this college, as well as the others noted in Table 7.1, demonstrates the efforts to which Singapore's MOE has gone to create the best global learning environments for both Singaporean citizens and global talent. There is a broad range of types of education available, for different types of learners. This will keep Singapore's labor force diverse and agile. Adult learners are also returning to the classrooms of these universities and colleges, to upskill the older population as well.

The example of the creation of Yale-NUS College is just one petri dish in Singapore's higher education laboratory. These institutions are the front line of preparation for 4IR, but they are only one piece of a grandeur effort to assist Singaporeans and the economy in the era of 4IR. Two large initiatives, SkillsFuture and Smart Nation, are working with and alongside Singapore's institutions of higher education to prepare the population for living and working in a fully digital era.

SkillsFuture

> SkillsFuture is a national movement to provide Singaporeans with the opportunities to develop their fullest potential throughout life, regardless of their starting points. Through this movement, the skills, passion and contributions of every individual will drive Singapore's next phase of development towards an advanced economy and inclusive society. … Skills mastery is more than having the right paper qualifications and being good at what you do currently; it is a mindset of continually striving towards greater excellence through knowledge, application and experience.[49]

SkillsFuture is a government-led initiative to help Singaporeans adjust their mindsets and their capacities for the automation economy. This is

[49] "SkillsFuture," Government of Singapore, accessed December 28, 2017, http://www.skillsfuture.sg/AboutSkillsFuture.

important, as many nations are focused on taxing robots and preparing for universal basic income (UBI). Some, including Bill Gates,[50] have suggested that a tax on robots could be used to distribute the economic gains from automation efficiencies that will not be reaching the unemployed. This is not Singapore's approach. The cultural belief in the value and necessity of work is strong, and citizens have a deep-rooted commitment to working for a living. The initiative of SkillsFuture is culturally responsive in that way.

The SkillsFuture initiative is based on four key thrusts. First, it is intended to help individuals make decisions about their education, training, and how this might align with their career. Formerly called the Individual Learning Portfolio (ILP), MySkillsFuture is a one-stop education, training, and career guidance website. The website is intended to align the acquisition and the utilization of skills for Singaporean citizens and is integrated into the nation's job bank.

Second, SkillsFuture runs an integrated high-quality system of education and teaching that responds to the shifts in 4IR technology and corresponding industry jobs. Third, the initiative representatives work with industry to ensure there is employer recognition for upskilling certificates and the corresponding promotion/compensation for mastery of skills. Fourth, SkillsFuture works to foster a culture that supports and celebrates lifelong learning across Singapore. Public messaging through posters, advertisements, and the like is common around the city-state.

SkillsFuture is organized into five levels of support: student, junior level, middle management, senior management, and career switcher. There are multiple opportunities across Singapore for adult learners in particular. Research is expanding into better understanding how to engage adult learners as well.[51] For many, re-education and upskilling is expensive. Singapore has three different funding mechanisms in place for this. There are SkillsFuture credits for all Singaporean citizens so that they do not have to have the financial means to afford this upskilling. There are also SkillsFuture qualification awards and student awards and an Earn and Learn program. SkillsFuture works with institutions of higher education but also maintains the Institute of Lifelong Learning, where Singaporeans

[50] Kevin Delaney, "The robot that takes your job should pay taxes, says Bill Gates," *Quartz*, February 17, 2017, https://qz.com/911968/bill-gates-the-robot-that-takes-your-job-should-pay-taxes/.

[51] Grace McCarthy, "Motivating and enabling adult learners to develop research skills," *Australian Journal of Adult Learning*, vol. 55, no. 2 (2015): 309–330.

at all levels can take targeted courses to gain new skills. The intention is that labor disruption will be less socially alarming and economically challenging as a result. Furthermore, Singaporeans will be better prepared for the automation economy, benefiting themselves and the nation's economy.

Smart Nation Singapore

Smart Nation Singapore is separate government initiative developed to help citizens ease into the social and economic changes that are already emerging with the automation economy. Singapore launched its Smart Nation effort in December 2014. The approach expands from the idea of a Smart City, which emerged in the 1980s, and today involves the application of technology to sustainable and inclusive ICT connectivity. The technology supporting Smart Cities involves the Internet of Things (IoT) and a Wi-Fi-enabled network of sensors and devices all talking to each other to enhance life for city residents. But the ability of a city community to take advantage of such technologies requires a digitally literate population. Ezra Ho argues that Singapore was already a Smart City by 2014, but that the Smart Nation initiative "is about coordinating and intensifying the effort to develop the institutions, regulations, and talent for a hyper-connected, datafied urbanity."[52] In order for Singaporeans to take advantage of the higher education and SkillsFuture opportunities, they must have digital literacy. Digital literacy is demonstrated as technical and cognitive competence in a variety of areas. It is the "ideas and mindsets, within which particular skills and competencies operate, and about information and information resources, in whatever format"[53]; the most accurate definition of digital literacy is drawn from Allan Martin's work:

> Digital Literacy is the awareness, attitude and ability of individuals to appropriately use digital tools and facilities to identify, access, manage, integrate, evaluate, analyse and synthesize digital resources, construct new knowledge, create media expressions, and communicate with others, in the context of

[52] Ho, "Smart Subjects for a Smart Nation? Governing (Smart)Mentalities in Singapore," 3107.

[53] David Bawden, "Origins and Concepts of Digital Literacy," in *Digital Literacies: Concepts, Policies and Practices*, eds. Colin Lankshear and Michele Knobel (New York: Peter Lang Publishing, 2008), 19.

> specific life situations, in order to enable constructive social action; and to reflect upon this process.[54]

Having these skills is essential in order for a society to benefit from Smart Nation efforts and 4IR more broadly.

As detailed by Hoe Siu Loon, Singapore's digital literacy journey began in the 1980s with the National Computerization Plan.[55] Since then there has been a succession of government-led initiatives to upgrade the physical digital capacity as well as the human capacity of the nation including the National IT Plan of 1986, the IT2000 plan of 1992, the Infocom 21 plan of 2000, the Connected Singapore plan of 2003, the Intelligent Nation 2015 plan, and more recently in the Infocomm Media 2025 plan.[56] Smart Nation Singapore identifies five key domains in which digital technology can enhance the lives of citizens. These include transport, home and environment, business productivity, health and enabled aging, and public-sector services.[57]

The networks and structures put in place to implement Smart Nation Singapore are important to understand for those seeking to integrate such a program into their own higher education and lifelong learning national programs. In January 2016, Dr. Janil Puthucheary was appointed as the Minister of State, Ministry of Communications and Information and MOE, and placed in charge of the Smart Nation initiative. This was an important leadership position and is strategically placed across both ministries. In March 2016 the Smart Nation Fellowship program was launched to recruit and create a network of computer scientists and technology experts to collaborate with the government on how best to create projects for the public in line with adapting the population to a new way of living and working.[58] Then, in May 2016, the "Lee Hsien Loong Interactive

[54] Allan Martin, "DigEuLit - a European Framework for Digital Literacy: a Progress Report," *Journal of eLiteracy* 2, no. 2 (2005): 135–136.

[55] Hoe Siu Loon, "Defining a Smart Nation: The Case of Singapore," *Journal of Information, Communication and Ethics in Society* 14, no. 4 (2016): 323–333.

[56] Hoe, "Defining a Smart Nation: The Case of Singapore."

[57] "About Smart Nation," Smart Nation and Digital Government Office, last updated November 9, 2017, https://www.smartnation.sg/about-smart-nation.

[58] "IDA Launches Smart Nation Fellowship Programme to Foster a Network of Top Data Science and Tech Talents for Singapore," GovTech Singapore, March 7, 2016, https://www.tech.gov.sg/media-room/media-releases/2016/03/ida-launches-smart-nation-fellowship-programme-to-foster-a-network-of-top-data-science.

Digital Media (IDM) Smart Nation Award" was established to help make visible the good efforts of full-time polytechnic students working on interactive digital media projects that contributed to the Smart Nation efforts.[59] All of this effort on a national scale inevitably resulted in the need for more administration oversight. In May 2017, the Smart Nation and Digital Government Office (SNDGO) was formed under the Prime Minister's Office to prioritize and help deliver digital solutions for citizen and business needs.[60] Collaboration with primary, secondary, and tertiary education has been consistent throughout the development of Smart Nation Singapore and will likely become more important as the digitization process intensifies.

The government has also recognized the security risks associated with the new reality of life being online, plugged in, and always connected. For this reason cybersecurity is paramount.[61] Safeguarding the relevant systems and networks of Smart Nation for all citizens and compliance with the nation's privacy of data laws is a priority. A key element of Smart Nation is building computational capabilities in cybersecurity and data analytics. Here efforts are five pronged. For the youth of Singapore, IMDA Playmaker program is deployed to expose young children to technology while gaining educational experiences. Also, Code@SG is a movement that introduced coding and computational thinking to students in schools, again working to enhance digital literacy in preparation for 4IR jobs. Starting in 2018 Singapore will add Coding to 19 different schools' "O" Level subject testing in order to measure capacity better in this area. Smart Nation is also working with SkillsFuture to upgrade programming in the area of ICT. Lastly, Smart Nation will continue to invite Smart Nation Fellows to work on short stints to build robust cybersecurity systems.

[59] "Launch of Lee Hsien Loong Interactive Digital Media Smart Nation Award," Prime Minister's Office Singapore, May 6, 2016, http://www.pmo.gov.sg/newsroom/launch-lee-hsien-loong-interactive-digital-media-smart-nation-award.

[60] "Milestones," Smart Nation and Digital Government Office, last updated January 5, 2018, https://www.smartnation.sg/about-smart-nation/milestones.

[61] Smart Nation and Digital Government Office, "About Smart Nation."

Conclusion

The purpose of Singapore's approach is that Smart Nation, SkillsFuture, and the efforts of Singapore's institutes of higher education will combine to upskill and educate a workforce and citizenship that is uniquely educated for 4IR. This is how Singapore is planning to shift its populations' skill sets. Singaporeans will have opportunities throughout their lifetime to learn new skills. The efforts are characterized by three main thrusts. They are working to make a more digitally literate and technologically competent population through the Smart Nation and SkillsFuture initiatives. They are creating cohorts of ideation experts through unique higher education opportunities like Yale-NUS College, Singapore University of Technology and Design, and Duke-NUS Medical School. Finally, Singapore is internationalizing its population and creating a more globally savvy and connected citizenry.

What Singapore is doing is expensive. But pieces can be adapted. Benchmarking a nations' digital literacy is a good first step. From here government, NGO, and MNC training programs for a variety of skills should be rolled out. Internationalization of education is important, and higher education institutions can reach out to peer institutions around the world to establish tighter connections with student and faculty exchanges.

The impacts of 4IR are still emerging in Singapore. How will they know if Singapore is succeeding in these efforts? The goal has been set to maintain 2–3% economic growth per year. Three key indicators to monitor in this area will be GDP growth, unemployment, and foreign work permit allocations. It will be telling to follow the number of employment passes and permanent resident visas issued by the Singaporean government. If these numbers continue to drop substantially, one anticipated correlation will be an increase in 4IR-relevant jobs filled by Singaporeans.

The policies and programs being erected to address technological unemployment and to prepare for 4IR are not without their detractors. The ever-present connectivity that automation brings clashes with some notions of privacy. This analysis of Singapore's approach does not address the viability of the effort as a whole in Singapore to apply elsewhere. Rather, the efforts in Singapore are presented as an example of the multi-pronged approach being taken so as to suggest how other nations might adapt such a combination of efforts as is appropriate to their cultural and legislative context.

Singapore has invested heavily in higher education as a government tool for economic development for its citizens to exploit. It boasts two of

the world's best universities and several others who are delivering quality education. Lifelong learning has been identified as the essential element for success in the era of 4IR. We do not know what is coming next, so we must prepare minds that are agile, flexible, and cooperative. SkillsFuture and Smart Nation are programs which address the labor disruption pending from automation. Combined with new and innovative high-quality institutions of higher education such as Yale-NUS College, Singapore is well poised to capture the potential benefits of 4IR.

All countries should examine the Singaporean education system as they develop digital literacy programs so that their citizens are able to harness the benefits of 4IR. What is replicable and scalable from the case of Singapore is difficult to tell. Singapore has the financial means to put large sums of money and human capital into the retooling of its entire education system. The overall lesson is that nations need to be preparing for change. The status quo will likely result in significant unemployment in most countries, thus adapting some of Singapore's innovative policies will help offset this. For those nations in which quality higher education is only attained by a select few, there are exciting opportunities to leapfrog more advanced economies that will be locked into brick and mortar solutions and tied down by bureaucratic legacies. In preparation of 4IR, Singapore is deploying a multi-faceted strategy that merits rigorous appraisal by other countries and institutions of higher education.

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CHAPTER 8

Adopt Fast, Adapt Quick: Adaptive Approaches in the South African Context

Bo Xing, Lufuno Marwala, and Tshilidzi Marwala

The Fourth Industrial Revolution (4IR): New Data Resources

We live in a world where resources are becoming scarce while human needs continue to increase. According to Arthur O'Sullivan, Steven Sheffrin, and Stephen Perez,[1] the resources that humans utilize for production can be broadly classified into three types:

1. Natural resource: land, mineral, oil, natural gas, water, and so on.
2. Capital resource: machines, durable equipment, tools, infrastructure, buildings, and so on.
3. Human resource: physical labor, intellectual effort, knowledge, skills, experiences, leadership, entrepreneurship, and so on.

4IR unveiled artificial intelligence (AI), machine learning, robots, intelligent machines, 3D printing, bioscience technologies, Internet of Things

[1] O'Sullivan, Sheffrin, and Perez, *Macroeconomics: principles, applications, and tools* (New Jersey: Pearson Education, 2014).

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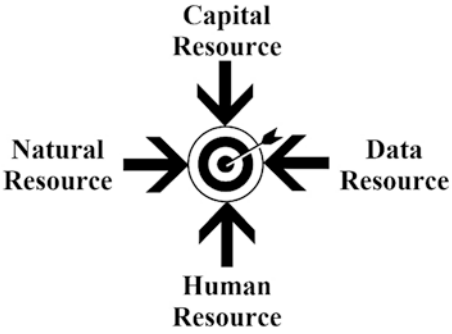

Fig. 8.1 New production resources: data

(IoT), and cyber-physical systems (CPSs). These developments are shaping a new data economy. As a new critical feedstock for this round of macro-economic developments (see Fig. 8.1), these data resources, though abundant and ubiquitous, constitute the 4IR inputs.

Approximately 100 gigabytes of data can be generated within a second of a self-driving car begining to operate. Some people refer to "Big Data" as "massive data." However, the most commonly used definition is called 3 Vs.[2] It was proposed by Doug Laney, a distinguished analyst at Gartner: Big Data is generally defined as "high volume, high velocity, and/or high variety information assets that require new forms of processing to enable enhanced decision making, insight discovery and process optimization."[3]

Without access to data and optimal use of it, machine learning and AI will not lead to new developments. Data are akin to raw material. They allow people to see beyond the digital world and pave the way to faster communications (e.g., customer-centered design), improved coordination mechanisms (e.g., smart logistics and smart factories), and innovative collaborations (e.g., new business and cooperation models across counties and continents).[4]

Companies have increased their capacity to analyze and make use of Big Data. For instance, Internet companies manage data that give them

[2] Ibar Yaqoob et al., "Big data: from beginning to future," *International Journal of Information Management* 36, no. 6 (2016): 1231–1247.

[3] "Big Data," Gartner, accessed January 10, 2018, https://www.gartner.com/it-glossary/big-data.

[4] Harvey Lewis et al., "Big data 2.0: new business strategies from Big Data," *Deloitte Review* 12, (2013): 1–17; James Manyika et al., *Big data: the next frontier for innovation, competition, and productivity* (New York: McKinsey Global Institute, 2011).

enormous power (e.g., Alphabet, Amazon, Apple, Facebook, and Microsoft),[5] while industrial and retailer giants collect data that make them more competitive (e.g., Siemens, GE, McDonald, and Tesla).[6] Data are said to be a driver of growth and transformation, the true invisible hand behind 4IR. It is emerging as a means for governments, private sectors, and organizations to improve accuracy and trustworthiness,[7] and it offers the hidden insights that have the potential to shape and influence the manufacturing, social, and service environments.[8] Therefore, harnessing the power of Big Data will determine enterprises' likelihood of success in the future.[9] Like previous sources of information, data are believed to promote neo-infrastructure, neo-businesses, neo-monopolies, neo-politics, and most importantly new economic models/systems. However, unlike earlier sources of information, data are extracted, mined, refined, assessed, purchased, and sold in distinct ways. In the 4IR age, property rights and use of data are likely to generate conflict.

The Fourth Industrial Revolution (4IR): Renewed Human Resource

Though the 4IR is staged to drive inclusive benefits, it could also challenge our society and hinder (social/socio-economics) development by replacing human capital with machines. The workforce, therefore, needs to have greater access to higher education and education of quality. Low-skilled work will become scarcer in the future as predictable tasks are replaced by machines. Both high-skilled and low-skilled workers need to be either retrained or educated differently. The fast advancement of various technologies has led to partial or full automation of many job positions. Although many of us worry about the possibility of a situation in which human labor is replaced by automation and 4IR technologies, it is also

[5] The Economist, "The world's most valuable resource," *The Economist*, May 6–12, 2017.

[6] Dominic Barton and David Court, "Making advanced analytics work for you," *Harvard Business Review* 90, no. 10 (2012): 78–83.

[7] IBM, *Understanding Big Data so you can act with confidence* (Somers: IBM Corporation, 2014).

[8] The Economist, "Fuel of the future," *The Economist*, May 6–12, 2017.

[9] Kazumasa Oguro, "Big data – key to the 4th industrial revolution," *Japan SPOTLIGHT*, (2016): 24–27; Lidong Wang and Guanghui Wang, "Big data in cyber-physical systems, digital manufacturing and industry 4.0," *International Journal of Engineering and Manufacturing* 4, (2016): 1–8.

important to recognize that job automation can be a positive change,[10] at least when:

1. Jobs are characterized by monotony and boredom: These kinds of jobs are typically based on a routine and demand more concentration than critical thinking (e.g., assembly line positions). Humans are prone to feeling dissatisfied when involved in monotonous and boring jobs, which could potentially result in absenteeism, high employee turnover, injuries, and health deterioration.
2. Jobs are full of unfavorable dangerousness: These jobs are common in sectors like manufacturing, mining, nuclear energy, and other heavy industries. Introducing automation could prevent unnecessary injuries and deaths while also increasing productivity.
3. Jobs involve simple-step transactions: Automatic teller machines (ATMs) are exemplar in this category, mainly because they operate 24/7. Similar advanced technologies could make simple-step transactions more efficient than when they are managed by conventional human operators.
4. Jobs that are unwanted by humans: It has become increasingly difficult to recruit qualified crew members willing to stay away from home for months while drifting at sea. When carrying non-perishable goods, autonomous cargo vessels are more convenient because they allow to save on accommodation expenses for the crew and remove the bulk of associated utilities (e.g., heating and plumbing).

With the above discussion as a backdrop, it becomes evident that investment in human capital is necessary for multiple purposes such as finalizing key decision making, problem solving, and process monitoring (e.g., onshore unmanned ship control room). Even in a fully automated working environment, humans are still indispensable. When new technologies are firstly introduced, humans are needed to finalize and coordinate implementation tasks. When systems are put into operation, people need to perform a set of non-straightforward maintenance duties. Humans also have the capacity to upgrade their skills by taking over the jobs when automation

[10] Jack Phillips and Patricia P. Phillips, *High-impact: human capital strategy: addressing the 12 major challenges today's organizations face* (New York: American Management Association, 2015); The Economist, "Technology quarterly: ghost ships," *The Economist Technology Quarterly* 410, no. 8877 (2014): 3–4; Pavel Tsvetkov, *Nuclear power – control, reliability and human factors* (Rijeka: InTech, 2011).

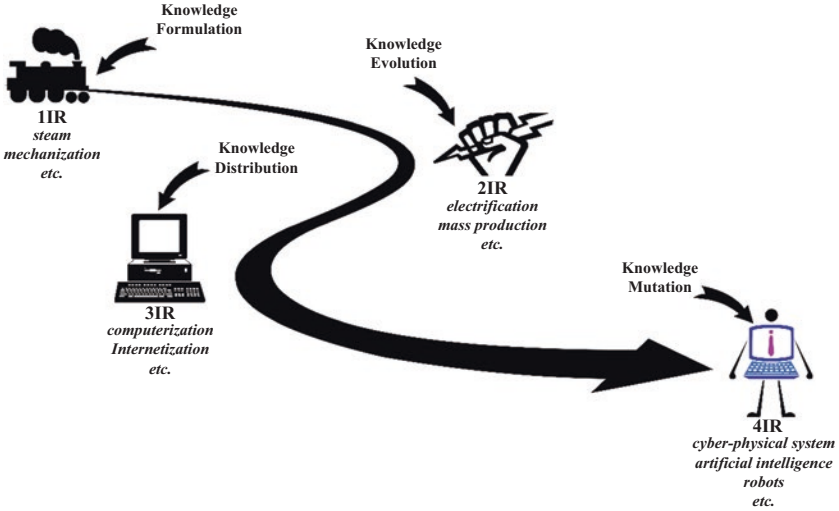

Fig. 8.2 4IR: Dissolving human and machine boundary

fails. This analysis can help us to reach the conclusion that human capital is not outdated in the era of 4IR, but it requires enhanced training.

From the first to third industrial revolutions, machines outperformed humans in terms of mechanical tasks. This led to a shift in the duties associated with human labor, from mechanical tasks to cognitive tasks in the service industry. 4IR technologies (see Fig. 8.2), with the advent of AI, are poised to outperform humans in cognitive tasks.

The current trend shows that AI-based algorithms for Big Data are becoming a substitute, in the workplace, for a wide range of non-routine cognitive tasks.[11] The computerization of jobs will leave a large proportion of human labor unemployed. Erik Brynjofsson and Andrew McAfee showed that there is a strong negative relationship between wages and educational attainment and the probability of computerization.[12] Future professionals will have to shift to new areas and types of work.

[11] Carl B. Frey and Michael A. Osborne, "The future of employment: how susceptible are jobs to computerisation?," September 17, 2013, https://www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf.

[12] Brynjofsson and McAfee, *Race against the machine: how the digital revolution is accelerating innovation, driving productivity, and irreversibly transforming employment and the economy* (Lexington: Digital Frontier Press, 2012).

Minding the Truth and Fact Gap

Although the vast abundance of data resources and well-projected human resources illustrates a bright picture of the brave new world of 4IR, there is a looming gap between truth (how data resources are being exploited) and fact (how human resources are managing to adapt).

Upcoming Truth: Granular Computing Mereology

AI is a computerized process that mimics human behavior in problem solving. Though the early days of AI were full of failures, this research area resurfaced in the form of neural networking, thanks to numerous researchers devoting themselves to integrating rigorous mathematical theories (e.g., statistical inference approaches, topological representation, and relational matrix theory) in AI.[13] From the public viewpoint, AI appears powerful enough to trigger 4IR and automatically solve a wide range of global issues. Despite the fact that there is still a huge gap between computerized and humanized problem solving, scientists are trying very hard to close such gap.[14] According to Hobbs, an exclusive feature of human problem

[13] Tshilidzi Marwala, *Computational intelligence for missing data imputation, estimation and management: knowledge optimization techniques* (New York: IGI Global, 2009); Tshilidzi Marwala, *Finite-element-model updating using computational intelligence techniques: applications to structural dynamics* (London: Springer-Verlag, 2010); Tshilidzi Marwala, *Condition monitoring using computational intelligence methods: applications in mechanical and electrical systems* (London: Springer-Verlag, 2012); Tshilidzi Marwala, *Economic modeling using artificial intelligence methods* (London: Springer-Verlag, 2013); Tshilidzi Marwala, *Artificial intelligence techniques for rational decision making* (London: Springer International Publishing, 2014); Tshilidzi Marwala, *Causality, correlation and artificial intelligence for rational decision making* (Singapore: World Scientific Publishing, 2015); Tshilidzi Marwala and Evan Hurwitz, *Artificial intelligence and economic theory: skynet in the market* (Cham: Springer International Publishing, 2017); Tshilidzi Marwala, Ilyes Boulkaibet, and Sondipon Adhikari, *Probabilistic finite element model updating using Bayesian statistics: applications to aeronautical and mechanical engineering* (Chichester: John Wiley & Sons, 2017); Tshilidzi Marwala and Monica Lagazio, *Militarized conflict modeling using computational intelligence* (London: Springer-Verlag, 2011); Bo Xing and Wen-Jing Gao, *Innovative computational intelligence: a rough guide to 134 clever algorithms* (London: Springer International Publishing, 2014).

[14] Bo Xing and Tshilidzi Marwala, *Smart maintenance for human–robot interaction: an intelligent search algorithmic perspective* (Cham: Springer International Publishing, 2018).

solving is the ability to conceptualize the world in different levels and enjoy free mobility across them.[15]

Consider a well-debated smart factory scenario in 4IR. When a production manager is involved in drafting a production plan, he/she only needs a coarse-grained factory model during the early stage of mental planning. At this stage, the whole factory may be encoded as a rough block diagram composed only by key workshops while temporarily ignoring details. As soon as a sketched plan is available, our human manager will reconsider some previously neglected minutiae to form a fine-grained factory model. During this phase, if global information needs to be considered, he/she can swiftly switch back to the former coarse-grained model. This trait is the hallmark of human intelligence. However, when we turn our attention to our counterpart, intelligent machines, the situation changes dramatically. Although computers have almost every bit of data about a factory (e.g., machine conditions, worker profiles, tool availability, building environment, and inventory list) accumulated in their storage medium, it is still difficult for them to create different representation models based on these data, let alone switching back and forth among models with distinct granularity levels.

In this regard, humans have already embarked on solving this problem using their own intelligence. Although the physical implementation of intelligent machines is probably quite different from that of human brains, an in-depth understanding of the human brain's basic working rules is still an often-indispensable requirement when it comes to designing machines that use AI. Built on various efforts, granular computing slowly arises as a suitable candidate in fulfilling the requirement for understanding the genuine human intelligence. The core idea of granular computing is inspired by humans' capacity to process information in a multi-level granular manner. The foundations of granular computing can be traced back to the renowned mereological theory of things. Granular computing is made possible by breakthroughs in AI, fuzzy sets, and rough sets. Granular computing is helping machines better imitate humans' problem-solving capacity.

[15] Jerry R. Hobbs, "Granularity," (Paper, Proceedings of the 9th International Joint Conference on Artificial Intelligence, Los Angeles, CA, August 1985). https://www.ijcai.org/Proceedings/85-1/Papers/084.pdf.

Upsetting Fact: Gradual Commencing Ideology

4IR is gradually introducing a shift in the way in which production in the economy is conducted. Consequently, new jobs that are significantly different from those that currently exist will be created. Accordingly, the skill set that will be required in the new economic paradigm will also need to change. Thus, the new skill set will be driven by 4IR and drive the new economic paradigm. However, training and employment systems are currently structured in such a way that people spend their first 25 years training for jobs and spend the rest of their lives working. This is starting to change so that individuals continue to be trained and learn for the rest of their lives, which means that lifelong learning will no longer be reserved for the ambitious but will be a common feature required by every worker. However, this transformation is not easily achievable since everyone is a victim of a subtle force: lag. In 4IR, lag can be perceived as obsolesces, because most people who fall behind may feel that they will not be able to catch up. Some of them pretend to be adaptable by adopting new technologies and strategies early.

In this regard, the higher education sector must be responsive to this shift by not only adopting several new technological developments (e.g., digital open courseware and online educational resources) but also acknowledging the achievement gap—a disparity exhibited by different student groups in terms of enrolment and academic performance. In 4IR, university graduates must be significantly different from those of yesteryear. Any new training paradigm developed by higher education institutions needs to show a reasonable balance between two factors, namely, time-to-adoption (technology-related elements) and time-to-adaption (human-related elements).

Minting an ADAPTIVE Solution

The result of the three previous revolutions, for countries that were able to benefit from them, was a broadened provision of social services such as health care and education for their populations. This was the outcome of an increase in economic productivity (more resources to distribute among the population) and a more efficient distribution of the resources. Thus, it is expected that the South African higher education sector will be both a beneficiary and a driver of the 4IR. As such, this education sector is expected to use 4IR as a means to overcome some of the challenges that it

is currently facing. These challenges include but are not limited to, broadening access to higher education for South Africans living in poverty; a decline in state funding for higher education; and creating a larger pool of next-generation academics and improving the quality of higher education offered in the South African tertiary institutions. Amid these obstacles, the higher education system must grapple the notion of creating the future workforce. Indeed, the conjecture is that the 4IR will have a positive impact on all dimensions of higher education. To meet this expectation, we propose an ADAPTIVE solution in this section, which covers the factors of accessibility, digital literacy, acceleration, pan-regionalization, transformation, inclusiveness, vision, and engagement. The ADAPTIVE solution is presented in the following subsections largely determined by the alphabetically appearing sequence (acronym); however, some important overlapping themes are addressed across subsections. Although the University of Johannesburg (UJ) is intensively used (accompanied by other South African universities occasionally) for illustrative purpose, the scope and boundary of "ADAPTIVE" is by no means limited to any specific higher education institution or scenario.[16]

Accessibility

From a historical viewpoint, the developmental cycle of higher education has gone through elite, mass, and post-mass stages.[17] With the forthcoming 4IR, the higher education system is expected to enter its next stage (i.e., a scheme of universal education that intends to keep the whole population adaptable to dramatic societal and technological changes).[18] Our first ADAPTIVE factor, accessibility, is thus selected to address the issues that many modern higher education institutions are currently facing. The following two practices expound how UJ is striving to achieve this goal.

[16] University of Johannesburg, "University of Johannesburg Corp Video 2017," filmed July 2017 at Johannesburg, University of Johannesburg video, 5:52, https://www.youtube.com/watch?v=QF2hDivUhos.

[17] Jung C. Shin, Gerard A. Postiglione, and Futao Huang eds., *Mass higher education development in East Asia: strategy, quality, and challenges* (New York: Springer International Publishing, 2015).

[18] Molly N. N. Lee, "Higher education in Malaysia: national strategies and innovative practices," in *Mass Higher Education Development in East Asia: Strategy, Quality, and Challenges*, eds. Jung C. Shin, Gerard A. Postiglione, and Futao Huang (New York: Springer International Publishing, 2015), 105–118.

Accessible Environment

As more universities embrace strategic plans that assimilate digital technology and introduce more active learning in traditional lecture halls, they have also reconfigured their physical surroundings to spur these teaching and learning shifts. Educational arrangements are being adjusted to encourage project-based interactions that take a range of factors (e.g., mobility, flexibility, and multi-device usability) into account. Among myriads of redesigning and planning activities, educational practitioners should also acknowledge the importance of offering disabled students equal and integral access to higher education.[19]

At UJ, we fully recognize the central role of addressing disability in achieving our transformative goals and aspirations to offer full access to higher education. As such, all issues related to disability receive equal consideration from the perspectives of both UJ's policy and broader institutional mandate. In addressing disability, UJ operates through a holistic approach that emphasizes a continued improvement of disability-friendly infrastructure (e.g., the availability of assistive devices) through the adaptation to pedagogic approaches that support diverse learning needs (e.g., curriculum design, living environment, sporting facilities, online systems, and technological settings) in order to support diverse learning needs in a reasonably accommodating and practical manner.[20]

Accessible Curriculum

In the era of 4IR, lifelong learning becomes a necessity for humans to compete with machines.[21] Therefore, students (or more precisely people)

[19] Adams S. Becker et al., *NMC horizon report: 2017 higher education edition* (Austin: The New Media Consortium, 2017), 1–60; Laura Hartrey, Suzanne Denieffe, and John S.G. Wells, "A systematic review of barriers and supports to the participation of students with mental health difficulties in higher education," *Mental Health & Prevention* 6, (2017): 26–43; Daniel Mara, "Higher education for people with disabilities – Romanian education experience," *Procedia - Social and Behavioral Sciences* 142, (2014): 78–82.

[20] University of Johannesburg, "Annual report 2015," 2015, https://www.uj.ac.za/about/Documents/reports/UJ_AnnualReport2015ONLINE.pdf.

[21] "Lifelong learning: continuous training and development is the key to business success," *Development and Learning in Organizations* 27, no. 2 (2013): 23–25; Andries de Grip and Wendy Smits, "What affects lifelong learning of scientists and engineers," *International Journal of Manpower* 33, no. 5 (2012): 583–597; Tiffany D. Fishman and Linsey Sledge, *Reimagining higher education: how colleges, universities, business, and governments can prepare for a new age of lifelong learning* (New York: Deloitte University Press, 2014).

should be capable of learning and working anywhere, with uninterrupted access to study materials, and keeping their peers within reach. Higher education institutions thus need to make a great leap in creating more platforms for students and faculty to be collaborative and productive.[22] With this understanding, the Executive Leadership Group of UJ has recently made the pioneering decision to form a partnership with a leading international online education provider company to enrich curriculum offerings. Several pressing areas linked to 4IR (e.g., cyber-citizenship) are under careful consideration.[23]

Digital-Savvy

4IR is characterized by widespread advancement in digital technologies. Although the ubiquity of these technological and digital tools is already well documented, their usefulness and effectiveness are not yet clear. If those in possession of these new technologies cannot generate a meaningful use of them, then their spread will have less positive impact.[24] Our second ADAPTIVE factor—digital-savvy—is thus chosen to address this often-overlooked issue by many modern higher education institutions and invention workshops. The following two practices elaborate how UJ is exerting itself toward mitigating the negative side effects.

Digital Fluency

The workforce for 4IR is expected to be digital-savvy and seamlessly work with different media sources as well as novel technologies. An essential factor for cultivating a desired level of digital fluency is to recognize that superficial knowledge of a certain device or software is far from enough; students and faculty must possess the ability to make connections and

[22] Becker et al., *NMC horizon report*.

[23] University of Johannesburg, "Annual Report 2015."

[24] Gabriela Grosseck "To use or not to use web 2.0 in higher education?," *Procedia Social and Behavioral Sciences* 1, no. 1 (2009): 478–482; Lucinda Kerawalla et al., "An empirically grounded framework to guide blogging in higher education," *Journal of Computer Assisted Learning* 25, no. 1 (2009): 31–42; Agnes Kukulska-Hulme, "How should the higher education workforce adapt to advancements in technology for teaching and learning?," *Internet and Higher Education* 15, no. 4 (2012): 247–254; Paul A. Tess, "The role of social media in higher education classes (real and virtual) – a literature review," *Computers in Human Behavior* 29, no. 5 (2013): A60–A68.

perceive implications among the tools they use and their intended outputs. The accumulated knowledge and the resultant competence of leveraging technology in inventive means will allow people to quickly adapt from one scenario to another. The ownership of this campaign must be shared and sustained by all divisions within an institution, given that digital fluency affects almost every aspect of modern teaching and learning.[25] Bearing this in mind, UJ has been actively developing a rich collection of digital information resources and initiating various online presentations of electronic books throughout the past decade. In order to cope with the trend of high penetration rate of mobile technologies among students and staff, the functionality of our uLink (a primary portal for students and staff) has been upgraded to accommodate email and mobile registration and provide a new interface—uConnect. In addition, a series of efforts were made to release the newest version of UJ's app—uGo.[26] Apart from these, a lab under the Centre for Academic Technologies (CAT) was also established to foster innovation in teaching and learning, for example, developing media artifacts that facilitate one-on-one collaborative and interactive teaching and learning.

Digital Literacy

For people to succeed in the twenty-first-century workplace and beyond, innovative and productive technology usage that encompasses modern practices is vital. The importance of digital literacy lies in that it transcends the conventional technological skill-gaining process by offering a better understanding of digital surroundings, which in turn will equip people with an intuitive adaptability to new contexts and the ability to coordinate creatively with others.[27] To address this issue, UJ offers a set of in-depth digital literacy training sessions to first-year students. In response to the ever-increasing demand for these sessions, the following strategy was prepared and conducted: standardization of Library Information Literacy modules that cover the fundamental knowledge to make use of the library via textual display or video interaction.[28]

[25] Joanne Gikas and Michael M. Grant, "Mobile computing devices in higher education: student perspectives on learning with cellphones, smartphones & social media," *Internet and Higher Education* 19, (2013): 18–26.

[26] University of Johannesburg, "Annual Report 2015."

[27] Becker et al., *NMC horizon report.*

[28] University of Johannesburg, "Annual Report 2015."

Meanwhile, UJ reached a three-year collaboration agreement with the City of Johannesburg Metropolitan Government. Under the Digital Ambassadors program, approximately 3000 entrepreneurial youths from across the City of Johannesburg received dedicated training at the UJ via an open-sourced, cloud-based learning management system. Over a period of 18 months, the project deployed successful candidates across the Johannesburg city area to promote digital literacy among local residents to facilitate the use of various online tools and enable personalized benefits for their career development.[29]

Acceleration

Nowadays, new knowledge is generated and accumulated every day at an astonishing rate. Under these circumstances, it is necessary to nurture a novel breed of alternative educational modes. For instance, developing cost-efficient, shorter, weight-reduced, content-wide, and diverse learning modules.[30] In the hypercompetitive environment that we face with 4IR, accelerated learning and training are paramount.[31] Therefore, our third ADAPTIVE factor entails acceleration with the goal of eliminating the mismatch between demand and supply, that is, the heads that employers are eagerly hunting for and the mind-sets that students have forged upon graduation. The following two practices demonstrate how UJ is accelerating itself in accomplishing this transmutation.

Accelerated Learning

To meet such pressing needs, UJ has designed a set of short learning programs (SLPs) to acquaint participants with the new thinking methods in several fast-growing fields. In its essence, an SLP has a certain amount of credit values (e.g., less than 120 credits), lasts no more than six months in average, and is offered by various accredited content providers (inward or

[29] University of Johannesburg, "Annual Report 2015."

[30] Anya Kamenetz, "The $10,000 business degree," September 23, 2017, www.fastcompany.com/3015844/the-10000-business-degree; Francesca Pucciarelli and Andreas Kaplan, "Competition and strategy in higher education: managing complexity and uncertainty," *Business Horizons* 59, no. 3 (2016): 311–320.

[31] John S. Brown, "Learning in and for the twenty-first century," in *CJ Koh Professorial Lecture Series No. 4* (Singapore: Nanyang Technological University, 2013), 1–21; Fishman and Sledge, *Reimagining higher education*.

outward) in the target field. In addition, statistical results showed that the number of Continuous Professional Development (CPD) programs for accreditation from different service providers in South Africa has increased.[32]

By now, UJ has over 200 SLPs available within nine faculties all year-round. These courses include both face-to-face and e-learning components and are catered to both national and international participants. For example, UJ has partnered with several organizations such as the United Nations Economic Commission for Africa (UNECA), the Business Communication and Writings for Intergovernmental Professionals (BCWIP) course, the UJ International Office for the University of Johannesburg English Language Programme (UJELP), and Cornell University to establish an SLP in law. Overall, SLPs offer alumni, students, and staff the prospect to enhance their knowledge and develop a culture of lifelong learning.

Accelerated Profession Development

The insistence on introducing more hands-on, technology-assisted, and content-tailored learning activities has affected entire operational systems of many universities, specifically teaching practices. The traditional image of a university instructor was that of a sage enlightening the audience. However, with regular collaboration, interaction, and innovation among students, instructors have redefined themselves as guides, lightening on the side. Under this new normal, students need professional mentors and coaches who join them to explore new front-lines, solve problems, and obtain concrete skills. To enable this, institutions must provide professional development support to their faculty. In light of this requirement, UJ implemented the Accelerated Academic Mentorship Programme (AAMP) in 2015. This initiative was designed to facilitate a transformation of the academic cohort, particularly in the development of the next generation of academic leaders. The specific emphasis of the AAMP initiative was placed on the establishment of a far more diverse and representative academic cohort.

[32] University of Johannesburg, "Annual Report 2015."

Pan-regionalization

The consensus is that the landscape of higher education has been dramatically transformed during the last three decades, after the international dimension was added in the picture. As the world becomes more interrelated, globalized, and integrated, universities, businesses, and governments delve deeper into relationships and opportunities with their peers. The most recent effort has been to focus on regionalized institutional cooperation and exchange. In Africa, various regional organizations (e.g., African Union, Association of African Universities, and the Association for the Development of Education in Africa) are actively supporting the "African Higher Education Harmonization" movement. The growing significance of higher education pan-regionalization is testified by the establishment of regional institutions such as Pan-Atlantic University, Pan-African University, and Pan-European University and numerous intra- and inter-regional alliances and agreements.[33] Our fourth ADAPTIVE factor is thus dedicated to pan-regionalization. In line with this trend, UJ has established an Institute for Pan-African Political Thought and Conversation, which is regarded as an activating agent that positioned UJ as the African epicenter for critical thinking and conversation. Meanwhile, UJ partnered with Nanyang Technological University (NTU) in Singapore, to establish the Johannesburg Institute for Advanced Studies (JIAS). The JIAS is the first Pan-Africa-Pan-Asia establishment that aims to generate global advancement by offering spaces for leading world thinkers to deliver crucial reflections.

Transformation

In the 4IR, a cultural transformation is indispensable to promote progressive learning. In other words, the structure of institutions must be organized in a way that spurs the development and intersectionality of new concepts, popularizes successful cases inside or outside of the university enclosure, and rewards student-focused teaching innovation.[34] Accordingly, we choose transformation as our fifth ADAPTIVE factor. The following two aspects demonstrate how UJ is transforming itself inside out.

[33] Fishman and Sledge, *Reimagining higher education*.

[34] Sharon Rider, Ylva Hasselberg, and Alexandra Waluszewski, *Transformations in research, higher Education and the academic market: the breakdown of scientific thought* (Dordrecht: Springer Science+Business Media, 2013).

Institutional Culture

In 2015, UJ celebrated its tenth anniversary. When UJ was officially established (a merger of three renowned higher education institutions) in 2005, it immediately set out on a path to steer the institution toward a transformative goal. Among various achievements, UJ has been recognized as one of the strongest university brands within South Africa. Transformation at UJ is mainly coordinated by the designated Transformation Unit with incoming contributions from many other divisions and units. The five carefully selected motifs covered by the Transformation Plan clearly indicate the depth and breadth of UJ's transformational determination—ranging from the underlying institutional culture through a shift toward active leadership and employment equity to the outpaced academic performance and a mission that holds student success at its core.[35]

In terms of institutional culture, UJ is committed to provide an empowering institutional environment and culture that promote diversity and consider the social, ethnic, and class representation of the Johannesburg metropolitan area. UJ's students and staff are as diverse as the community it serves. A tenet that has been embedded into UJ's institutional culture is innovation. Innovation is best nourished within a university when people with diverse cultures, views, principles, and attitudes can interact with one another with mutual understanding and a trustable spirit.

New Establishments

To cope with the potential disturbances brought by 4IR, UJ has also set up several new establishments for students to better seize the emerging opportunities out of the university fence. On July 1, 2017, UJ officially launched its College of Business and Economics (CBE), which is a strategic combination of the different innovative strengths of two UJ faculties: the Faculty of Management and the Faculty of Economic and Financial Sciences. The aim of CBE is to position UJ as a leader in African commerce by providing an excellent, practice-driven commerce education. UJ also aims to satisfy South Africa's need for additional medical practitioners and is working to establish the Johannesburg Medical School. After having successfully completed a series of benchmarking tests and in-depth analysis, UJ is positively approaching the goal of opening the doors of this medical school in the near future.

[35] University of Johannesburg, "Institutional transformation plan," 2011, https://www.uj.ac.za/about/Transformation-Unit/Documents/UJ_Institutional_Transformation_Plan.pdf.

Inclusiveness

The 2017 Summer Davos Summit was held in China, and the key theme of that forum was inclusiveness, that is, how the 4IR can be inclusive and not generate a situation where individuals fend for themselves. Aligned to this broad consensus and UJ's strategic goals of being globally excellent, the sixth ADAPTIVE factor is inclusiveness. This selection actually mirrors a unification between various activities that UJ is living up to, in order to address the need for further inclusion and UJ's unique institutional culture as reflected in its slogan: "Transformation through reconciliation—Together creating an inclusive and caring vibrant African city university."[36] In this regard, UJ has developed a new post-graduate diploma specialized in inclusive education. This new program offers an alternative to online distance learning.

Visionary

Today, learning has moved to the top of the business priority list in terms of sharpening skills, enlarging the leadership pipeline, and stimulating employee incentives. At times when every organization has to reassess its learning environment, a fresh vision needs to be implemented to create an optimized learning experience that touches everyone involved in a significant way.[37] The Chief Learning Officer (CLO)[38] is thus no more an envisioned position in many businesses when it comes to creating a suitable learning culture. Motivated by this new consideration, the ADAPTIVE solution encompasses vision as its seventh factor. The following two movements show how UJ is creating a vision for the future.

Internationalization

The internationalization division was formed to undertake a set of work that is central to UJ's vision of becoming "an International University of choice, anchored in Africa, dynamically shaping the future."[39] Through

[36] University of Johannesburg, "Institutional Transformation Plan."

[37] Abrie Olivier and Trevor Page, *Rewriting the rules for the digital age: 2017 human capital trends report for South Africa* (New York: Deloitte Touche Tohmatsu, 2017).

[38] Josh Bersin et al., eds., *Global human capital trends 2015: leading in the new world of work* (New York: Deloitte University Press, 2015).

[39] University of Johannesburg, "About Us," accessed January 10, 2018, https://www.uj.ac.za/about.

internationalism, UJ is poised to strengthen its scholarly engagement and soft power to influence transformative agendas on national, regional, and continental levels. UJ will also integrate to the immense global higher education landscape. The Executive Management Committee ensures that UJ's leadership fosters an environment where failure is normalized as part of the learning process. Some specific actions include recruiting students and faculty members from around the world, integrating them into UJ's life, decolonizing the curriculum, developing international partnerships, bolstering international collaboration, and facilitating student and staff mobility to name a few.

Expanding the Academic Core

In addition to normally practiced initiatives in contributing to an enriched learning experience through academic expansion, UJ's Global Excellence and Stature Fund also injected valuable academic resources into several flagship programs, like the newly established Institute for Intelligent Systems (IIS).[40]

South African universities are already involved in AI research. The University of Pretoria (UP) established a Computational Intelligence Research Group or CIRG based in the Department of Computer Science in 1998.[41] Its areas of focus include swarm intelligence, evolutionary computation, neural networks, and artificial immune systems. These techniques have been applied in this group for optimization (e.g., scheduling), classification, prediction, data mining and clustering, image analysis, bioinformatics, and financial analysis problems. The University of Cape Town established the Robotics and Agents Lab (RAL), which focuses on developing autonomous robots.[42] In 2011, the Centre for Artificial Intelligence Research (CAIR) was founded as a joint research center between the University of KwaZulu-Natal and the Council for Scientific and Industrial Research (CSIR).[43] CAIR is a national research network that undertakes foundational, directed, and applied research into numerous domains of AI. In 2016, CAIR was expanded to include universities: the University of Cape Town, University of KwaZulu-Natal, North-West University, UP,

[40] University of Johannesburg, "Dismantling data obstacles with intelligent systems for national benefit," November 13, 2017, https://www.uj.ac.za/newandevents/Pages/Dismantling-data-obstacles-with-intelligent-systems-for-national-benefit.aspx.

[41] University of Pretoria, "CIRG," 2017, http://cirg.cs.up.ac.za/visitPage.php?pageID=1701.

[42] University of Cape Town, "RARL," 2017, http://www.rarl.uct.ac.za/.

[43] CAIR, "CAIR," Accessed July 25, 2017, http://cair.za.net/.

and Stellenbosch University. CAIR is coordinated and funded by the CSIR Meraka Institute and Department of Science and Technology (DST) respectively. These initiatives still have to find a place in the broader curriculum of several South African institutions.

In this regard, UJ has emerged as a leader in reengineering its curriculum so that it is centered on 4IR.[44] For example, UJ IIS focuses on systems intelligence and cognitive computing, Big Data analytics and deep learning, digital revolution and machine learning, and industrial application of intelligent systems and cognitive computing. UJ has committed to change the curriculum so that it ensures that graduates can participate in 4IR. Such changes include ensuring that engineers understand social sciences and humanities.[45] AI is a computerized process that mimics human behaviors in learning and solving problems. Accordingly, AI machines assume responsibilities in society that require them to be designed as moral entities. Therefore, an engineer and a computer scientist with a better understanding of the human moral framework (psychological and social) should be an average graduate from the higher education system. UJ also plans to introduce a degree in computer sciences and culture.[46]

At the same time, by making full use of the Strategic Tutor Fund in combination with other specifically allocated resources, UJ has established one of the largest tutor support programs in Africa. In stimulating the decolonization movement, which is expected to redirect the knowledge flow from the developed world to the developing world, UJ has also appointed Nobel Laureate Prof. Wole Soyinka to actively lecture and engage in public discourse on global politics and development. Having Soyinka at the university is a clear signal that Africans have the capacity to contribute to 4IR.

Engagement

It is widely agreed that organizations stand to harvest the benefits of having a highly committed workforce.[47] However, this sought-after commitment does not come from nowhere. Recently, both the business world and the academic research community have been particularly interested in taking

[44] Fengu Msindisi, "Forging a new academic path," July 2, 2017, http://www.news24.com/SouthAfrica/News/newsmaker-forging-a-new-academic-path-20170702-2.

[45] Msindisi, "Forging a new academic path."

[46] Msindisi, "Forging a new academic path."

[47] Astrid von Kotze and Shirley Walters, *Forging solidarity: popular education at work* (Rotterdam: Sense Publishers, 2017).

advantage of engagement (the integration of several classical commitment and motivation theories) to harness the power of commitment.[48] For instance, in Europe it is commonly believed that the universities' remarkably affluent intangible resources (e.g., knowledge and expertise) can and have to be better exploited to make a more visible contribution toward economic development and society as a whole, aside from preparing graduates, and that a wider engagement movement could stimulate this.[49] In line with the theme of this chapter, our ADAPTIVE formulation concludes by enfolding engagement. The following two types of engagements describe how UJ is deriving benefits from a broader engagement.

Community Engagement

As the third essential purpose of the university, community engagement (CE) is embedded in UJ's mission as indicated by the powerful declaration "inspiring its community to transform and serve humanity through innovation and collaborative pursuit of knowledge."[50] There are four key values that UJ highlights, namely:

1. Imagination: developing a cosmopolitan identity.
2. Conversation: engaging meaningfully with one another.
3. Regeneration: developing sustainability through creative contribution.
4. Ethical foundation: participating in and helping the community.[51]

In addition, UJ recognizes three types of CE, namely service learning, community-based research, and organized outreach. As an engaged university, UJ's goal is to use its learning, teaching, research, and CE capa-

[48] Josh Bersin, "Becoming irresistible: a new model for employee engagement," *Deloitte Review* 16, (2015): 1–19; Louis Efron, *Purpose meets execution: how winning organizations accelerate engagement and drive profits* (New York: Bibliomotion, Inc., 2017); Marylene Gagné, *The oxford handbook of work engagement, motivation, and self-determination theory* (New York: Oxford University Press, 2014); Keith J. Roberts, "Community engagement in Indian higher education: financial and partnership trends," *International Journal of Educational Development,* (forthcoming). https://doi.org/10.1016/j.ijedudev.2017.03.005.

[49] Simon Whittemore, "The JISC business and community engagement programme," in *Trends, Discovery, and People in the Digital* Age, eds. David Baker and Wendi Evans (Witney: Chandos Publishing, 2013), 185–203.

[50] University of Johannesburg, "Mission, Vision and Values," accessed January 10, 2018, https://www.uj.ac.za/about/Pages/vision-mission-and-values.aspx.

[51] University of Johannesburg, "Mission, Vision and Values."

bilities to make a substantial impact to the social, economic, and educational advancement of Johannesburg, the Gauteng province, South Africa, and beyond. For example, over the last eight years, UJ has held an annual event aimed at women's empowerment organizations. Other initiatives include the art for AIDS international organization workshop, the Nelson Mandela International Day initiative, and the UJ CE volunteer champion programs.[52]

Stakeholder Engagement

Stakeholder engagement (SE) impacts on UJ's reputation, both nationally and internationally. In this regard, UJ gathered media exposure, which promoted UJ's experts as thought leaders, ensuring a broader diffusion of the UJ brand to improve the university's profile. A number of international media houses, such as the BBC and CNN, have used UJ academics as experts. In addition, several initiatives have taken place within UJ in 2015, which included the Orange Carpet Open Day and the staff/teacher cupcake interactions program. On the other hand, the Institutional Advancement Division manages most of the non-academic SEs, some of which include 1001 Seats of Knowledge, the alumni relations event, the 555 project, and the "missing middle" initiative.[53]

Minuting: A Case Study in the Context of South Africa

Historically, the economic performance of the mining industry has been among the best in South Africa. Today, the mining industry continues to play an important role in promoting population growth, regional development, industrial diversification and growth, and research innovation. In terms of research innovation, in 2013, BASF Group launched a mining laboratory in Johannesburg to offer innovative solutions for mineral processing and extractive metallurgy, while South African universities and research organizations are focusing on projects that use satellite monitoring to detect the deformation of land surfaces, mitigate the environmental

[52] University of Johannesburg, "Community engagement report," 2014, https://www.uj.ac.za/about/Documents/reports/community%20engagement%20report%202014.pdf.

[53] University of Johannesburg, "Annual report 2015."

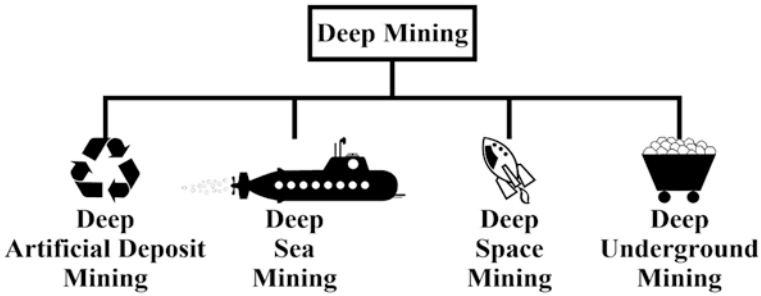

Fig. 8.3 Deep mining paradigm

impact of quarrying, and support the rehabilitation of post-mining processes.[54]

As several reports argue, it could change not only business, but many other sectors. It is a good opportunity for the mining industry to embrace new technologies, rethink their operating models, and find new productivity gains. Under 4IR, manufacturing is going digital and thus becoming smart. In light of this, a number of remarkable technologies like deep learning algorithms, mobile technologies, Big Data analytics, and automation are converging. For instance, engineers in big construction firms like Hitachi hosted a new project called "Smart Excavator" to deploy Big Data analytics to optimize the vehicle routing strategies at the coalface.[55] Another example proposed by Sweden's Lulea University of Technology is "smart Rockbolt," which focuses on using sensors to measure both vibrations and strain.[56] Indeed, mining's future depends on technological innovation (for both deep learning and deep mining, see Fig. 8.3). Neal Froneman, the CEO of Sibanye Gold, South Africa's largest producer of the metal, told the *Financial Times* on May 13, 2017: "with conventional mining, the mining industry can look forward a sharp

[54] Keith Campbell, "Space based: earth observation satellites starting to bring benefits to mining sector," *Mining Weekly*, June 2, 2017, http://www.miningweekly.com/article/earth-observation-satellites-are-beginning-to-bring-benefits-to-the-mining-sector-2017-06-02/rep_id:3650.

[55] Jamie Carter, "Deep learning: how the mining industry got smart," June 14, 2016, http://www.techradar.com/news/world-of-tech/deep-learning-how-the-mining-industry-got-smart-1322890.

[56] Carter, "Deep learning: how the mining industry got smart."

decline in gold production by 2019~20 and for mining to die out almost completely by 2033."[57]

Mingling "ADAPTIVE" Solution with Smart Mining

Mining the earth's natural resources, in addition to causing negative environmental impacts, is arduous, dangerous, and hazardous for people involved. Smart mining (with the ultimate goal of autonomous mining) is a viable alternative in the age of 4IR. Nevertheless, the automaton economy does not mean the complete elimination of humans from mining operations. A mine typically has a limited lifespan that ranges from short-term geographical investigation, possibility analysis, feasibility evaluation, through mid-term system design and construction, production initiation, equipment decommissioning, to long-term system disposition and environment protection. Thus, humans are still required at many stages of mining operations where the use of scientific methodologies is necessary to gain an in-depth understanding of the process. In this section, we demonstrate how the proposed ADAPTIVE solution is being implemented at UJ-Sibanye Mining Leadership program[58] to equip students with the necessary skills to cope with the smart mining future.

Accessibility

In 2017, in line with the requirements from the South African Department of Higher Education and Training (DHET), Council of Higher Education's (CHE) new Higher Education Quality Sub-framework (HEQSF), and Engineering Council of South Africa (ECSA), the Faculty of Engineering and the Built Environment (FEBE) at UJ introduced South Africa's first accredited Bachelor of Engineering Technology (BEngTech) degree and Built Environment Bachelors qualifications.[59] The new three-year BEngTech degree is specifically structured (as shown in Fig. 8.4) and is combined with the conventional Bachelor of Engineering

[57] Joseph Cotterill, "Mining's future depends on technological innovation," *Financial Times,* May 13, 2017.

[58] Saurabh Sinha and Hennie Grobler, "UJ-Sibanye engineering "mining leadership"," April 3, 2017, https://goo.gl/OPbzdI.

[59] FEBE, "The First in SA to roll out accredited BEngTech and built environment Bachelors qualifications," filmed October 2016 at Johannesburg, University of Johannesburg video, 2:26, https://www.youtube.com/watch?v=nvqeeVMTSSg.

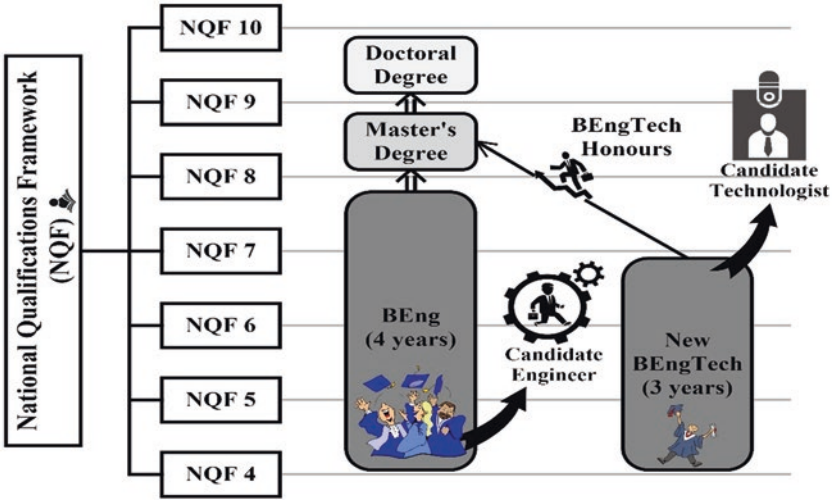

Fig. 8.4 The structure of UJ's new engineering and built environment qualifications

(BEng) degrees to cater for South Africa's in-demand technology occupations.

At the same time, several new master's degrees were introduced as follows:

1. Research-based degrees: Mineral Resource Governance and Sustainable Mining.
2. Coursework-based degrees: Structural Engineering, Sustainable Energy, and Sustainable Mining.

In terms of the enrolment in mining-related disciplines, UJ has also witnessed a dramatic increase over the past decade (see Fig. 8.5).

Digital-Savvy

With the growing popularity of wearable technology, CPSs will become a new norm in 4IR, elevating the role of numerical simulations in both education and practical applications. Among others, UJ has been implementing wearable technology to provide an immersion experience. It is actively exploring the possibility of introducing virtual reality (VR) assistive devices to enhance undergraduate exposure and employability skills in mining-specific domains.

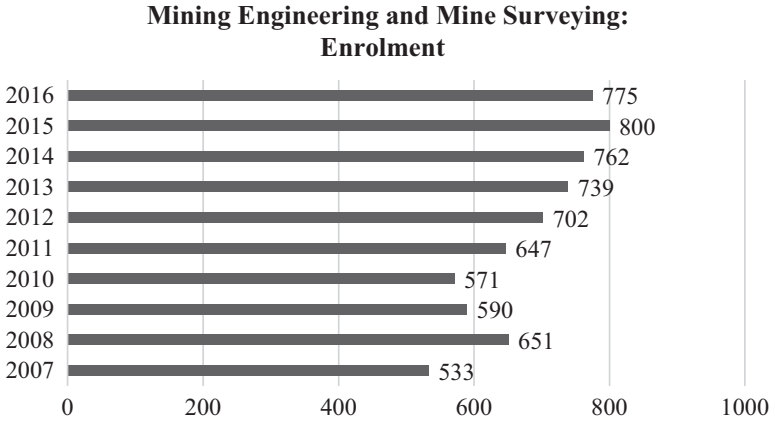

Fig. 8.5 The UJ's mining discipline: enrolment overview

Acceleration

It is widely agreed that the pedagogical shift toward authentic learning (e.g., project-based, challenge-driven, competency-involved) can trigger students' motivation to grasp wealthier hands-on, real-world experiences. As such universities have made active learning a priority over the outdated rote learning. Students are treated no more as passive participants and absorbers of knowledge. Instead, they stand at the center of the stage as active contributors to the ecosystem of knowledge production and use. In other words, there is no need for students to wait until graduation to test their skills since they applied them through various innovative means (e.g., practicing, experiencing, building, challenging, contesting, and demonstrating). To meet this requirement, UJ has built a mock mine environment at its Doornfontein Campus, which includes a 180-meter-long haulage connected with a 32-meter-high elevator shaft and a workshop complex. Such emulated facility can simulate real mining conditions that offer students an authentic mining learning experience through practical engineering, construction, and observation methodology during laboratory and tutorial sessions.[60] The mock mine further enhances the students' competitiveness by exposing them to other engineering disciplines (e.g., mechanical engineering, and electrical and electronic engineering).

[60] University of Johannesburg, "Annual Report 2015."

In addition to its educational purposes, the mock mine is also used for applied research objectives, developing and verifying smart mining-related technologies such as fiber-optical sensors, visible light and/or power line communications, indoor navigation techniques, and innovative urban mining mode (e.g., mine dumps and landfills).

Pan-regionalization

To increase UJ's regional impact, its Faculty of Engineering and the Built Environment also enabled a number of collaborative master's degrees with regional and international leading bodies:

1. Master of Foundry Engineering: Offered in collaboration with TU Berg Akademie Freiberg in Germany.
2. Master of Mineral Governance: Offered in Collaboration with the African Institute for Economic Development and Planning (IDEP).

Transformation

As an affirmation of UJ's strong research tradition, the South African National Research Foundation (NRF) has awarded several new research chairs to UJ, which deserve to be mentioned for the following reasons:

1. UJ was awarded five new South Africa Research Chairs in 2015.
2. UJ received the maximum that could be awarded within a particular year.
3. All five research chairs, including the industrial development chair, are held by UJ's stellar woman academics.

In addition to these recognitions, the newly NRF-funded Centre of Excellence of Integrated Mineral and Energy Resource Analysis (CIMERA) positions UJ as a leading institution in leveraging smart mining development. These transformative efforts have been fruitful. According to the recent QS World University Rankings by Subject, UJ has made a significant jump in its global ranking for mining engineering.[61]

[61] Sinha and Hennie Grobler, "UJ-Sibanye engineering "mining leadership."

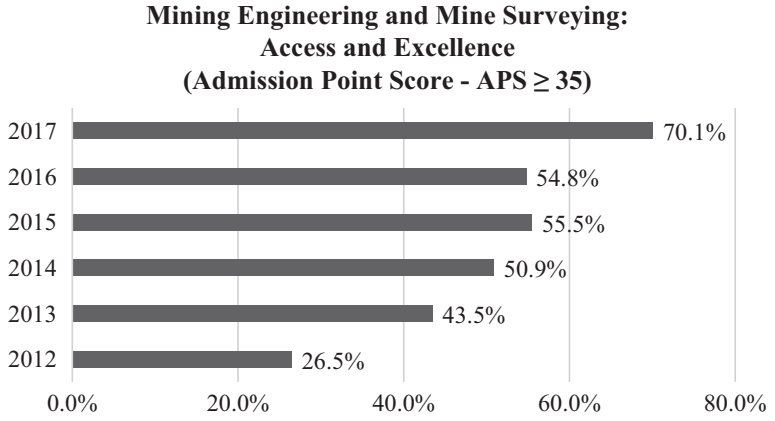

Fig. 8.6 The UJ's mining discipline: access and excellence overview

Inclusiveness

The transformation of both the mining industry landscape and the mining education system does not necessarily mean that the university has to leave any students behind. Conversely, UJ has experienced a steady growth in terms of high-achieving student enrolment and disadvantaged student enrolment (see Figs. 8.6 and 8.7).

Visionary

According to National Academies of Sciences Engineering and Medicine,[62] the future economic growth and competitiveness of a country largely depend on its innovation capacity, which is mainly sourced from the new knowledge and trained graduates produced by universities. However, the highly complex technical and societal problems that countries encounter can no longer be effectively addressed by a conventional higher education model. The single university research group led by an individual main investigator is likely not going to keep pace with the large-scale changes emerging in industry. Instead, these puzzles can be dealt with properly only when multiple institutions with different fields of expertise work

[62] National Academies of Sciences Engineering and Medicine, *A new vision for center-based engineering research* (Washington, D.C.: The National Academies Press, 2017).

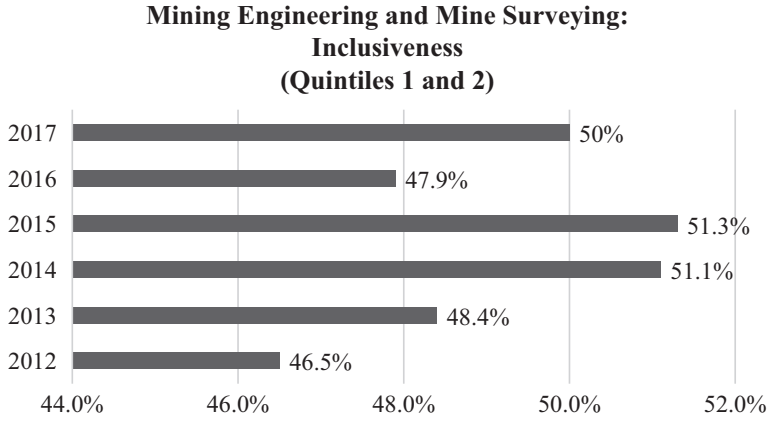

Fig. 8.7 The UJ's mining discipline: inclusiveness snapshot

collaboratively. The example of the Engineering Research Centre (ERC) in the United States is a positive example of the education opportunities that can be developed with government-university cooperation.

Many such collaborative opportunities are emerging in South Africa. For example, to ensure that South African universities continue to be a source of innovation, economic advancement, and educational excellence, the Gauteng University vice-chancellors signed a memorandum of understanding (MoU) at UJ on May 24, 2017, with the Premier of Gauteng, South Africa. The UJ's Vice-Chancellor together with Vice-Chancellors from other neighboring universities has come into an agreement to form a partnership with the Gauteng Provincial Government through collaboration on several key areas such as energy, security, and environment sustainability.[63] It is too early to tell what impacts such collaborations will have, but the preparation is essential as 4IR arrives in South Africa and around the world if we are to prepare a workforce of relevance.

[63] University of Johannesburg, "Gauteng University Vice-Chancellors partner with Government to strengthen research and innovation: The University of Johannesburg," May 25, 2017, https://www.uj.ac.za/newandevents/Pages/gauteng-university-vice-chancellors-partner-with-government-to-strengthen-research-and-innovation.aspx.

Engagement

In partnering with the DST via its Technology Innovation Agency (TIA), UJ has established a Process, Energy and Environment Technology Station (PEETS), which is committed to offer high-quality and professional engagement with stakeholders. Among different functionalities (e.g., training and demonstration, energy auditing, and environmental impact assessment), PEETS' main mission is to use suitable technological innovations to offer support to enterprise development in the energy and environment sectors.

Sibanye is an independent mining company based in South Africa, which holds and operates a portfolio of projects for high-quality gold and platinum group metals. Furthermore, Sibanye holds and manages significant extraction and processing facilities where gold-bearing ore is processed to yield gold. Sibanye is also currently investing in a number of long-term, sustainable organic projects. UJ is actively engaging with Sibanye to conduct mining-related research and innovation.

To engage with students, the newly forged mining degrees are also explained (by their academic leaders) through videos posted on popular online sites for the students' convenience. Some of them are listed as follows:

1. BEngTech degree in Extraction and Physical Metallurgy[64]
2. BEngTech degree in Mining Engineering[65]
3. BEngTech degree in Industrial Engineering[66]
4. BEng degree in Mine Surveying[67]

[64] FEBE, "Dr Didier Nyembwe - Bachelor of Engineering Technology in Extraction and Physical Metallurgy," filmed September 2016 at Johannesburg, University of Johannesburg video, 3:29, https://www.youtube.com/watch?v=DF76Z3zx-aM.

[65] FEBE, "Dr Steven Rupprecht – Engineering Technology (BEngTech) Degree in Mining Engineering," filmed October 2016 at Johannesburg, University of Johannesburg video, 4:05, https://www.youtube.com/watch?v=ct25c6yquaM.

[66] FEBE, "Dr Able Mashamba, Able – Bachelor of Engineering Technology Degree," filmed September 2016 at Johannesburg, University of Johannesburg video, 5:35, https://www.youtube.com/watch?v=UzetQwKRNOw.

[67] FEBE, "Dr David Wilson – Mine Surveying Bachelor's Degree," filmed September 2016 at Johannesburg, University of Johannesburg video, 4:10, https://youtu.be/VIPq7HXRHIs.

Conclusion

According to Jan Visser, human learning is related to human adaptive behavior, which can be identified at four levels[68]:

1. Preprogrammed and genetically transferable from one generation to another generation (e.g., fight and flight responses).
2. Inherited predisposition to acquire fundamental abilities (e.g., linguistic capability).
3. Commonly perceived learning level that involves deliberate acquisition of specific skills and knowledge. The outcome of this particular learning level may include motor skills, verbal abilities, knowledge acquisition, cognitive talent, and attitude capacity.
4. Transformed into a permanent disposition to interact with one's surroundings. Learning at this level is no longer limited to acquiring certain skills or knowledge pieces.

It is thus argued by Visser that true lifelong learning can only be achieved when one reaches the fourth level of learning.[69] However, since most people and societies have largely focused on the third level of learning, very little has changed over a long period of time. Now that 4IR is about to change many parameters of human existence dramatically, human learning should be treated as a complex system in which adaptive behavior is present in an integrated manner that comprises the four levels mentioned above. In this chapter, through the selected smart mining case, we emphasize how 4IR and specifically deep learning technologies are changing not only the mining sector but how learners are prepared to work in that sector. Through the ADAPTIVE strategy implemented in the UJ-Sibanye mining program, we illustrate how universities can help society to respond to such radical and sudden changes by deploying pedagogy that yields creative thinkers with practical skills.

[68] Visser, "The role of human learning in the information age: challenges and opportunities for Latin America and the rest of us," accessed December 28, 2017, http://www.learndev.org/dl/HumanLearnInfoAge.pdf.

[69] Visser, "Integrity, completeness and comprehensiveness of the learning environment: meeting the basic learning needs of all throughout life," in *International Handbook of Lifelong Learning*, eds. David N. Aspin, Judith Chapman, Michael Hatton, and Yukiko Sawano (Dordrecht: Kluwer Academic Publishers, 2001), 447–472.

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CHAPTER 9

The Fourth Industrial Revolution and Higher Education

Bryan Edward Penprase

The Fourth Industrial Revolution (4IR) is a concept widely discussed at venues such as the World Economic Forum (WEF) at Davos and within business leadership. Recent white papers describe how the 4IR will "shape the future of education, gender and work"[1] and how the 4IR will require "accelerating workforce reskilling."[2] A full exposition of the schema and framework of the 4IR has been presented in book form with an inventory of some of the key emerging technologies that are thought to drive the 4IR and some societal implications from the 4IR.[3] The 4IR as a phrase has its

[1] World Economic Forum, "Realizing Human Potential in the Fourth Industrial Revolution – An Agenda for Leaders to Shape the Future of Education, Gender and Work" (paper, World Economic Forum, Geneva, 2017).

[2] World Economic Forum, "Accelerating Workforce Reskilling for the Fourth Industrial Revolution An Agenda for Leaders to Shape the Future of Education, Gender and Work" (paper, World Economic Forum, Geneva, 2017).

[3] Klaus Schwab, "The Fourth Industrial Revolution: what it means, how to respond," January 14, 2016, https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/.

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roots in early analysis of the evolution of technology where the First Industrial Revolution arose from harnessing water and steam power toward more systematic and efficient forms of manufacturing. Typical descriptions of the First Industrial Revolution mention steam engines applied to the mining in Cornwall and the role of steam power in enabling massive increases in the scale of manufacturing. Steam power has been eloquently described as "the hub through which the spokes of coal, iron and cotton were linked."[4] The origin of the term industrial revolution itself traces to an 1884 work by Arnold Toynbee entitled *Lectures on the Industrial Revolution*.[5] Within Toynbee's description of the industrial revolution, the expansion of power and mechanical production became a revolution only from its coupling with a "political culture which was receptive to change,"[6] which included shifts in financial arrangements as well as other social progress. As one author put it, "the Industrial Revolution is not merely an acceleration of economic growth, but an acceleration of growth because of, and through, economic and social transformation."[7] Social and educational transformations from the first three industrial revolutions can provide a starting point in our consideration of the potential transformations in higher education arising from the 4IR.

Educational Responses to the First Two Industrial Revolutions

After the First Industrial Revolution, a vision for a new kind of curriculum began to form with more diverse degree options and new general education programs designed to produce breadth of study through the selection from a variety of elective courses. This type of education was described by the Harvard President Charles W. Eliot as "The New Education"[8] and offered a dramatic shift away from the dominant classical education eloquently outlined in the Yale Report of 1828.[9] University graduate

[4] William Rosen, *The Most Powerful Idea in the World – A Story of Steam, Industry and Invention* (Chicago: University of Chicago Press, 2010).

[5] Toynbee, *Lectures on the Industrial Revolution* (London: Rivingtons, 1884).

[6] Gavin Weightman, *The Industrial Revolutionaries* (New York: Grove Press, 2007), 3.

[7] Eric Hobsbawm, *Industry and Empire – The Birth of the Industrial Revolution* (New York: The New Press, 1968).

[8] Charles L. Eliot, "The New Education," *The Atlantic Monthly* XXIII, (1869).

[9] Yale University, *Reports on the Course of Instruction in Yale College: by a Committee of the Corporation and the Academical Faculty* (New Haven: Hezekiah Howe, 1828).

education within the United States and across the world was transformed by a widespread adoption of the German university model for postgraduate research, which enabled the rise of dozens research universities within the United States.

The Second Industrial Revolution is generally based in the period from 1860 to 1900, and is associated with new manufacturing technologies based on electricity,[10] which triggered additional changes launching what some have described as a "new economy."[11] An expansion of access to higher education and the proliferation of multiple types of higher education institutions in the United States and Europe produced a surge in discovery and helped consolidate and accelerate the growth brought about by the powerful new technologies. In the United States, the period of the first two industrial revolutions brought a large crop of innovative new educational institutions—founded through both public and private funding. The Morrill Act of 1862, passed in the middle of the Civil War and at the beginning of the Second Industrial Revolution, was intended to open educational opportunity "for the industrial classes"[12] and to enable higher education that is "accessible to all, but especially to the sons of toil."[13] These institutions, which took several decades to fully establish in each of the states, were intended to create a steady stream of newly trained technicians and engineers trained in the "practical avocations of life"[14] such as agriculture and the mechanic arts. Private philanthropy, fueled by the immense profits from new industries such as railroads, oil and steel, enabled the founding of institutions such as Stanford University (1885) and the University of Chicago (1890). Numerous small colleges were also founded such as Pomona College (1887), University of Southern California (1880) and a small technical institute known as the Throop

[10] Bruce C. Netschert and Sam H. Schurr, *Energy in the American Economy, 1850–1975: An Economic Study of its History and Prospects* (Baltimore: Johns Hopkins University Press, 1960).

[11] Andrew Atkeson and Patrick Kehoe, "Modeling the Transition to a New Economy: Lessons from Two Technological Revolutions," *American Economic Review* 97, no. 1 (2007): 64–88.

[12] Quoted in "The Morrill Act of 1862," University of Nebraska-Lincoln, accessed January 10, 2018, https://sdn.unl.edu/morrill-act.

[13] Quoted in Peter McPherson, "Celebrating the 125th anniversary of the Morrill Act of 1890," Association of Public Land-Grant Universities, July 15, 2015, http://www.aplu.org/news-and-media/blog/celebrating-the-125th-anniversary-of-the-morrill-act-of-1890.

[14] Roger L. Geiger, *The Land-Grant Colleges and the Reshaping of American Higher Education* (New York: Routledge, 2017), x.

College (1893), later to become Caltech. These institutions were founded a few decades after the beginning of the Second Industrial Revolution and were both enabled by and responded to the societal and economic changes rapidly building in the end of the nineteenth century. Most of these new institutions of higher education during the period of the Second Industrial Revolution were co-educational and helped foster an increased role for women in industrial and academic settings.

It is important to note that changes in society and education from both industrial revolutions are also difficult to separate from other causes, such as economic cycles and other titanic geopolitical shifts of the period that included the westward expansion and development of the United States, the rise of industrial Japanese and German states, and large global wars that dislocated economic activity and accelerated the development of science and technology. Some economists have also observed that the cyclic nature of economic activity arises from regular cycles of economic growth and recession, sometimes called Kondratieff waves.[15] Spectral analysis of world GDP growth has identified peaks in annual average GDP growth in the period of 1850–1875 and 1895–1913,[16] which coincides approximately with the conclusion of the first and the beginning of the Second Industrial Revolution. It has been noted by economists that whenever new technologies are introduced into an economy, there is a significant lag time for the technology to be fully adapted to a level where they provide measurable impacts on productivity. This lag between technological innovation and growth of productivity has been called a productivity paradox and has been attributed to the time it takes for training and experimentation with new technology to widely disseminate throughout society.[17] The results suggest that historically, changes within society and the impacts of technology on education require time to be fully realized. The profound changes in society and education that arose from the first two industrial revolutions spanned several decades, lagging well behind the initial introduction of the catalyzing technologies of steam and electricity.

[15] Nikolai. D. Kondratieff and W. F. Stolper, "The Long Waves in Economic Life," *Journal of Economic Statistics* 17, no. 6 (1935): 105–115.

[16] Andrey V. Korotayev and Sergey V. Tsirel, "A Spectral Analysis of World GDP Dynamics: Kondratieff Waves, Kuznets Swings, Juglar and Kitchin Cycles in Global Economic Development, and the 2008–2009 Economic Crisis," *Structure and Dynamics* 4, no. 1 (2010): 1–55.

[17] Atkeson and Kehoe, "Modeling the Transition to a New Economy."

The proliferation of new educational institutions and new curricula after the first two industrial revolutions enabled the technical and managerial capacity to implement the massive expansion of the economy and manufacturing that arose in the twentieth century. Seismic shifts in US higher education after World War II further advanced the societal changes made possible through the first two industrial revolutions. These changes included both a commitment to broader representation within higher education of veterans through the GI bill and the creation of community colleges in 1947, along with a massive expansion of the research mission of universities through federal funding. This expansion of research followed the publication of the report commissioned by President Truman entitled "Science: The Endless Frontier,"[18] and the creation of the National Science Foundation in 1950, which drastically increased the resources available for university scientists and shifted the incentive structures and curriculum within US higher education for decades to come. Within six years, federal funding for STEM subjects increased from $6 billion per year to over $35 billion between 1960 and 1966. In the development of its 3600 universities and colleges, the United States created a massive system which today enrolls more than 19 million students annually and grants nearly 3 million degrees with an employment of more than 3.6 million people, including 2.6 million faculty.[19] The higher education system in some ways can be considered as an industry in itself—accounting for more than $380 billion of economic activity—and this education industry itself is perhaps in need of an "Industrial Revolution."

Educational Responses to the Third Industrial Revolution

If history is to be our guide, the Third Industrial Revolution, which is generally attributed to computerization and web-based interconnectivity developed in the 1980s and 1990s, is only now having its rippling effects upon society, politics, economics and education. Within the Third Industrial Revolution, the expansion of access to higher education rose to

[18] Vannevar Bush, "Science The Endless Frontier," July 1, 1945, https://www.nsf.gov/od/lpa/nsf50/vbush1945.htm.

[19] Vartan Gregorian, "American Higher Education: An Obligation to the Future," *Carnegie Reporter*, 2014. https://higheredreporter.carnegie.org/introduction/.

even greater prominence with greatly increased diversity on campuses and globalization of academic research accelerated by online technologies. An intensified commitment to large-scale higher education across the world has resulted in increasing rates of participation in higher education in India, China as well as the United States. For example, in the United States the fraction of the population with some access to higher education has risen from 4% in 1900 to nearly 70% in 2000. The increasing diversity within student populations is also remarkable, with a 30% rise in enrollments in underrepresented groups, resulting in 38% of US college enrollments.

One of the largest ripples from the Third Industrial Revolution was the move toward online education, which culminated in the "Year of the MOOC" during 2012 as massive online open courses were expected to completely displace traditional in-person higher education and expand access to university education to millions of previously unserved students across the world. The revolution of higher education brought about by online courses is still ongoing, but is more likely to result in an integration of high quality, synchronous, in-person learning environments with online technologies to enable students to more rapidly build skills and knowledge asynchronously. One author has suggested a useful framework of disaggregating higher education activities between those that are intrinsically synchronous and personal, such as personal exploration, coaching and mentorship, from those activities that can be easily scaled and shifted online such as content transfer, and authoring and production.[20] Within the environment of increasing online content delivery and access to information, these more personal and "high-touch" components of the educational experience will become of increasing value and will not be easily replaced by technology.

Online and tech-enhanced teaching within universities is enabling both research universities and liberal arts colleges to more efficiently teach students with diverse backgrounds, and to open up their campuses to a more global community of both faculty and students. Small liberal arts colleges are working together to realize economies of scale with new types of technologies that improve on-campus experience for students through online math courses for incoming students, language

[20] Michael Staton, "Disaggregating the Components of a College Degree," August 2, 2012, http://www.aei.org/wp-content/uploads/2012/08/-disaggregating-the-components-of-a-college-degree_184521175818.pdf.

courses taught via videoconferencing, and new ways of merging social media with small-class seminars. One example of an initiative of this sort is the Liberal Arts Consortium for Online Learning (LACOL), which has brought together some of the leading US liberal arts colleges to explore these technologies.[21] Online education companies such as Coursera and EdX are partnering with larger universities to create newer and more interactive formats for their online courses and are developing dozens of new "stackable micro-credentials"[22] that link multiple online courses with in-person consultations with faculty and opportunities for students to conduct significant original capstone projects.

The Third Industrial Revolution has brought educators to an environment where access to information is immediate and free, shifting the focus toward active learning pedagogies that place a premium on collaboration within diverse teams in a project-based and peer learning environment.[23] Many of the most thoughtful responses to reform in STEM education in recent years have resulted in a greater emphasis on liberal arts and interpersonal skills imbedded within a more interdisciplinary curriculum. Examples include the Project Kaleidoscope Science initiative,[24] Liberal Studies in Engineering,[25] the American Physical Society SPIN-UP project[26] and the HHMI Scientific Foundations for Future Physician report.[27] All emphasize more interdisciplinary approaches in STEM that develop student capacity for collaboration and social interaction within STEM courses and curriculum.

[21] LACOL, "Liberal Arts Consortium for Online Learning," July 1, 2017, http://lacol.net/.

[22] Jeffery R. Young, "The New Frontier in Online Education," *Slate*, October 10, 2017, http://www.slate.com/articles/technology/future_tense/2017/10/microcedentials_are_the_new_frontier_in_online_education.html.

[23] Eris Mazur, "Farewell, Lecture?," *Science* 323, no. 5910 (2009): 50–51.

[24] Susan Elrod and Arianna J. Kezar, Increasing Student Success in STEM: A Guide to Systemic Institutional Change (Washington, D.C.: AAC&U, 2016).

[25] Louis Bucciarelli and David Drew, "Liberal Studies in engineering – a design plan," *Engineering Studies* 7, no. 2–3 (2015): 103–122.

[26] Robert C. Hilborn, Ruth H. Howes, and Kenneth S. Krane, eds., *Strategic Programs for Innovations in Undergraduate Physics* (College Park: The American Association of Physics Teachers, 2003).

[27] AAMC, *Scientific Foundations for Future Physicians* (Washington, D.C.: Association of American Medical Colleges, 2009).

Larger-scale responses in recent years to changing realities in the world have also resulted in entirely new institutions created with more global and more interdisciplinary curricula and a greater emphasis on strong collaborations between students within a residential community. One example is Yale-NUS College in Singapore, developed by Yale University and the National University of Singapore to provide a residential liberal arts college within Asia. Yale-NUS College offers an interdisciplinary curriculum which features literature and philosophy from both Eastern and Western cultures, a range of interdisciplinary science courses and quantitative reasoning, and courses in Modern Social Thought and Comparative Social Inquiry that enable students to collaborate and discuss some of the deepest issues of identity, family and social responsibility within the emerging globalized world of the twenty-first century.[28] A remarkable curriculum at Soka University of America in California develops students to become "global citizens" through intensive language study and required study abroad in a foreign language, as well as with wide-ranging core courses that explore "Enduring Questions" of humanity and how these questions are answered in a social context, drawing from classic works of Chinese, Indian and Greek philosophers, European social theorists and modern interpretations of twenty-first-century society in both the US and Asian contexts. Courses in both American Experience and the Pacific Basin and Modes of Inquiry further develop student capacity for discussion, dialogue and reflection within an international context.[29] A third curriculum being developed by Duke University for its new Duke-Kunshan University in China explores the concept of "rooted globalism," and blends an appreciation for a local culture with an exploration of international approaches to identity and society, and develops a framework for liberal arts in China in the twenty-first century.[30]

[28] Bryan Penprase and Terry Nardin, "Common Curriculum at Yale-NUS," July 1, 2017, https://indd.adobe.com/view/b8748bf2-c7a6-4cef-a1e6-9a30c36bfe80.

[29] Soka University of America, "General Education Curriculum," Accessed December 3, 2017, http://www.soka.edu/academics/general-education-curriculum/default.aspx.

[30] Kara A. Godwin and Noah Pickus, "Liberal Arts & Sciences Innovation in China: Six Recommendations to Shape the Future," *CIHE Perspectives*, November 1, 2017. https://www.bc.edu/content/dam/files/research_sites/cihe/pubs/CIHE%20Perspective/CIHE%20Perspectives%208_ENGLISH_13NOV2017.pdf.

Emerging Realities from the 4IR

The 4IR often is described as the result of an integration and compounding effects of multiple "exponential technologies," such as artificial intelligence (AI), biotechnologies and nanomaterials. One example of the emerging reality within the 4IR is the development of synthetic organisms (life from DNA created within computers and bioprinted) manufactured using robotic assembly lines, where nanomaterials provide immense improvements in the efficiency of production. The 4IR extends the paradigm of industrial revolution into a future when many of the elements of what we might consider industry—fixed and centralized factories, massive labor forces within large corporations—will no longer exist. The most familiar exponential technology is the exponential increase in computer power and decreasing cost in storage, which obeys a geometric relation commonly known as Moore's Law. The doubling of CPU power every 18–24 months has enabled new supercomputers to reach computation speeds of 300 quadrillion FLOPS (floating operations per second) in the latest supercomputer known as Milky Way 2,[31] an increase in speed of more than a factor of 300,000 in just two decades. When these digital exponential technologies are combined with other similarly rapidly expanding technologies—biotechnology, nanotechnology and AI—the combination of multiple exponentially developing technologies compounds and multiplies the pace of change. Some have described the convergence of these exponential technologies as providing a "singularity"—which will provide untold benefits to humanity as humans transcend biology, according to some authors.[32]

The WEF has defined a set of tipping points at which the technologies of the 4IR will become widespread enough to create massive societal change. These tipping points include the proliferation of 4IR technologies to levels where they make significant impacts on our lives and require shifts in employment and education. A survey of 800 high-tech experts and executives determined a series of dates by which tipping points would be reached. Examples include implantable cell phones by 2025, 80% of people with a digital presence by 2023, 10% of reading glasses connected to the internet by 2023, 10% of people wearing internet-connected clothes

[31] Michael A. Peters, "Technological Unemployment: Educating for the Fourth Industrial Revolution," *Journal of Self-Governance and Management Economics* 5, no. 1 (2017): 25–33.

[32] Ray Kurzweil, *The Singularity is Near* (New York: Penguin, 2005).

by 2022, 90% of the world population with access to the internet by 2024, 90% of the population using smartphones by 2023, 1 trillion sensors connected to the internet by 2022, over 50% of internet traffic directed to homes and appliances by 2024, and driverless cars comprising 10% of all cars in the United States by 2026. Many other predictions suggest extensive integration of AI in the 4IR workforce, such as AI members of corporate boards of directors, AI auditors and robotic pharmacists, proliferation of bitcoin in the economy, 3D printed cars by 2022, and transplants of 3D printed organs such as livers by 2024.[33]

One author has described the 4IR as a shift from non-renewable energy resources toward renewable energy enabled by biotechnology breakthroughs. This approach preserves the paradigm of the industrial revolution arising from new energy sources, and makes concrete predictions about the emerging bioeconomy that will fuel the future.[34] Increasing population and losses of arable land due to global climate change will require an increase in food production efficiency of over 50% by 2050, which places an imperative on 4IR technologies developing revolutionary new sources of food production. The emergence of biorefineries to use genetically modified microbes to provide a wide variety of useful chemicals as well as food components could be an essential part of the 4IR landscape. These biorefineries could make use of flexible food stocks that might include cellulose, biomass and simple sugars, to enable mass production of a diverse range of fuels, pharmaceuticals and food products in extremely large quantities and enable a reduction in the use of fossil fuels in the coming decades. Such organisms could also be used for environmental mitigation by removing various compounds from the environment such as toxic metals within landfills. Start-up companies are designing new organisms using standardized synthetic biology wetware allowing for the development of biological circuits and computers, and even for building materials to be grown using living materials known as "bio-bricks."[35]

The 4IR may also enable technological solutions to the environmental threats arising from the buildup of CO_2 and other greenhouse gases from the massive factories arising from our first two industrial revolutions. Some authors have predicted that global warming could render the earth

[33] World Economic Forum, *Deep Shift – Technology Tipping Points and Societal Impacts* (Geneva: World Economic Forum, 2015).

[34] James Philp, "The bioeconomy, the challenge of the century for policy makers," *New Biotechnology* 40, part. A (2018): 11–19. https://doi.org/10.1016/j.nbt.2017.04.004.

[35] D. E. Cameron, Caleb Bashor, and James Collins, "A brief history of synthetic biology," *Nature Reviews Microbiology* 12, (2014): 381–390.

uninhabitable through an increase of more than 10 °C, which would result in widespread crop failures and large fractions of the world's populations subject to heat exhaustion and potential death. The predicted increases in temperature will significantly reduce agricultural productivity by as much as 15% for every degree of warming.[36] New technologies could mitigate global warming by absorbing excess CO_2 using both bioengineered organisms and new materials within buildings.

In the new manufacturing regime enabled by 4IR technologies, sometimes called the Internet of Things (IoT), nearly anything can be designed on a computer and then printed on 3D printers that create objects in countless materials or even biological tissues. This capability will allow humans to turn data into things and things into data. 3D printing materials could range from the familiar thermoplastics found in traditional 3D printers to large-scale construction materials for buildings, to clumps of atoms 10 nm across.[37] This expansive IoT capability will enable printers to construct entire buildings, build microstructures with incredibly precise tolerances, or create biological structures for implants or even transplants of entire organs.

Higher Education's Response to the 4IR

The exact impacts of such 4IR technologies on society and the planet are still unknown—but the fact that they will bring profound and rapid change seems all but certain. The need for higher education to respond is urgent as the power of 4IR technologies for either positive social impacts or devastating environmental damage is upon us, as is the potential for irreversible loss of control over networks of powerful AI agents with increasing autonomy within financial sectors and within urban infrastructure.

Substantial changes to the science and technology curriculum will be required to allow for students to develop capacity in the rapidly emerging areas of genomics, data science, AI, robotics and nanomaterials. Such a 4IR STEM curriculum would reconsider the curriculum within the traditional "primary" sciences—biology, chemistry and physics—and

[36] David Wallace-Wells, "The Uninhabitable Earth," *New Yorker*, July 9, 2017, http://nymag.com/daily/intelligencer/2017/07/climate-change-earth-too-hot-for-humans.html.

[37] Neil Gershenfeld, "How to Make Almost Anything," *Foreign Affairs* 91, no. 6 (2012): 43–57.

place a higher premium for training in computer science subjects as a form of 4IR literacy. Within biology, new approaches might include training within introductory courses to discuss emerging areas such as synthetic biology and molecular design. Some examples of reshaped life science curriculum can be found at Stanford University, where a new Problem Solving in Biology course has students design experiments to develop cures to real-world pathogens such as Lyme disease and HIV, using authentic data from scientific literature,[38] or a new course in engineering biology that allows students to design their own life forms on computers and bioprint them to solve practical problems in medicine, public health and environmental management. These courses are a response to the emerging bioeconomy, which already exceeds $400 billion in the United States alone.[39] Within the Stanford curriculum is a new major known as bioengineering, which trains students at the "interface of life sciences and engineering"[40] and merges expertise and resources in the departments of medicine, biology and engineering. Similar innovations within chemistry include a worldwide proliferation of courses and degree programs in Green Chemistry, which blends chemistry, biology and environmental science to allow students to engage on real environmental problems such as synthetic fuels, bioplastics and toxicology, and to train students in techniques to reduce pollution.[41] New physics curriculum emphasizing 4IR collaborative skills is also being developed, based on projects where students design and build original musical instruments, cryptographic gadgets and other inventions collaboratively.[42] Additional educational responses to 4IR might require a restructuring of institutions to provide new science programs and departments in emerging interdisciplinary fields to more efficiently provide trained workers to help advance

[38] Martha Cyert, "Developing a New Introductory Biology Curriculum," Accessed November 2, 2017, https://vptl.stanford.edu/spotlight/developing-new-introductory-biology-curriculum.

[39] Drew Endy, "Yale-NUS College STEM Innovation Conference," April 27, 2016, http://steminnovation.sg/wp-content/uploads/2017/06/Endy_Yale_NUS_STEM_v1.pdf.

[40] Tom Abate, "New Bioengineering Major culminated department's evolution," October 22, 2015, https://engineering.stanford.edu/news/new-bioengineering-major-culminated-department-s-evolution.

[41] Liliana Mammino and Vânia G. Zunin, *Worldwide Trends in Green Chemistry Education* (Cambridge: Royal Society of Chemistry, 2015).

[42] Caroline Perry, "In Ap 50, Students Own their Education," September 23, 2013, https://www.seas.harvard.edu/news/2013/09/in-ap-50-students-own-their-education.

and accelerate the development of ever-more sophisticated biotechnology, nanotechnology materials and AI.

Any educational plan for the 4IR must be built upon the results of the Third Industrial Revolution described earlier, with its emerging development of hybrid online and in-person instruction, and efficient and seamless integration of global videoconferencing and a wide array of asynchronous educational resources. Blended instruction and optimization of flipped and online courses will make more efficient learning environments that can adapt for diversity in preparation of students. The Future of Education Report at MIT strongly emphasizes the need for leveraging online courses to strengthen the residential education for undergraduates and to also give more flexibility and modularity of courses.[43] Examples of effective blended environments include the supremely popular CS 50 course at Harvard,[44] the MIT introductory Electrical Engineering course, where course material is delivered entirely online with the in-person component focusing on laboratory and maker space time for students to build and test robots, and the MIT Circuits and Electronics course, which has been offered as an online course for residential students, who found the course to be less stressful and who appreciated the ease of scheduling and additional speed for receiving feedback in their assignments.[45]

Any effective 4IR education strategy must also include in equal measure a deep consideration of the human condition, the ways in which new technologies and shifting economic power impact people of all socioeconomic levels, and the threats that exist within a world that is increasingly interconnected, in a way that fosters deep intercultural understanding and an abiding respect for freedom and human rights. Such approaches favor an interdisciplinary and global curriculum in a residential context, such as is found in many liberal arts institutions. These approaches maximize the development of intercultural and interpersonal skills, which will be a hallmark of the future 4IR workplace.

[43] MIT, "Institute-wide Task Force on the Future of MIT Education," July 1, 2013, https://future.mit.edu/.

[44] Cordelia F. Mendez, "This is CS50," *Fifteen Minutes Magazine*, September 18, 2014, http://www.thecrimson.com/article/2014/9/18/this-is-cs50/.

[45] Nick Roll, "For-Credit MOOC: Best of Both Worlds," June 15, 2017, https://www.insidehighered.com/news/2017/06/15/credit-mooc-proves-popular-among-mit-students.

4IR Liberal Arts: An Ethical Imperative for Our New Human Condition

More than anything, the 4IR puts a premium on adaptability and in self-directed learning and thinking. Some authors have noted that the shelf life of any skill in the present-day environment has become increasingly short, requiring future workers to continuously update their skills and teach themselves about new technologies and new industries that may not have existed while they were being trained for their initial degrees. A further design requirement for education within 4IR would be to include a strong overlay of ethical thinking, intercultural awareness and critical thinking to enable for thoughtful and informed application of the exponentially developing technologies. A well-developed plan for a 4IR form of higher education will ensure that our students will graduate into a world that they can help shape with wisdom and skill, while building a future society we would want ourselves and our grandchildren to live in. Graduates of any 4IR higher education should be capable of advancing the material culture of our future world, while creating a culture which advances technologies sustainably and ethically.

Within Career and Technical Education (CTE), new frameworks need to be developed to respond to the increasing rate of change and the increasing complexity and volatility of employment. Such educational programs will need to shift emphasis away from routine tasks and, like the more academic curriculum, develop habits of mind and capacity for creativity within workers at all levels. One such framework for CTE suggests that an emphasis on soft skills such as career navigation, work ethic, and innovation will better prepare students for the emerging 4IR workplace.[46] Integration of 4IR technologies such as the IoT in both CTE and more academic settings requires a simultaneous treatment of rapidly changing technical details and building capacity for teamwork and collaboration within students.

The changing nature of work—which favors more flexible and shorter-term assignments—has been cited as a key factor to address within 4IR education. Future jobs within the 4IR technology sectors, AI, machine learning, robotics, nanotechnology, 3D printing, genetics and biotechnology, are expected to dominate in the coming decades. Within

[46] Jay W. Rojewski and Roger B. Hill, "A Framework for 21st-Century Career-Technical and Workforce Education Curricula," *Peabody Journal of Education* 92, no. 2 (2017): 180–191.

those sectors, employers and industries are projecting that social skills that include persuasion, emotional intelligence and capacity for teaching others will be at a premium.[47] Already employers have recognized the power of liberal arts for catalyzing entrepreneurship and for developing "people skills" which many large tech companies are actively seeking to help them develop new products and new marketing.[48]

Fourth Industrial Revolution Liberal Arts: New Elements to the Curriculum

The 4IR and its associated technologies such as biotechnology and AI challenge some of our fundamental assumptions of what it means to be human and the conditions of our relationship with the natural world. How should liberal arts respond to this new human condition? There are several key pieces that seem to be integral to a 4IR Liberal Arts Program.

The social dislocations from the 4IR have to be accounted for within a new 4IR liberal arts curriculum. Already we have seen the correlation between corporate earnings, productivity gains and wage increases break down. As smart AI-powered machines and other advanced technologies become more common within corporations, this trend is only expected to accelerate. The 4IR curriculum needs to respond to the political and social tensions that will accompany the accelerating pace of technological change, and to respond to the paradox of technologies that simultaneously increase democratization and centralize wealth and political influence. As described in one of the WEF reports, the political effects of the expansion and convergence of the physical, digital and biological worlds will be profound. This development will "enable citizens to engage with governments, voice their opinions, coordinate their efforts, and even circumvent the supervision of public authorities. Simultaneously, governments will gain new technological powers to increase their control over populations."[49]

With the evolution of online instruction and expanding uses of AI, new guidelines are needed to provide a theoretical basis for digital pedagogy. Some have called the old models of teaching "anthropocentric

[47] World Economic Forum, *The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution* (Geneva: World Economic Forum, 2016). http://www3.weforum.org/docs/WEF_Future_of_Jobs.pdf.

[48] George Anders, *You Can Do Anything: The Surprising Power of a "Useless" Liberal Arts Education* (New York: Little, Brown and Company, 2017).

[49] Schwab, "The Fourth Industrial Revolution."

humanism" and the new types of digital education "critical posthumanism." These approaches stress that digital education is more than a purely technical concern, as online environments change the dynamics of space and time to create new learning cultures that challenge our earlier notions of social interactions and enable new perspectives on our shared humanity, independent of geographic boundaries.[50] Such a curriculum can also help students grapple with the complex issues of relationships within online spaces and the philosophical dimensions of AIs that may approach or even surpass human intelligence. One author has created a "Cyborg Manifesto" to help explain the social reality for a cybernetic organism, which would be a "creature in a post-gender world"[51] where divisions between nature and culture, public and private and human and non-human break down. These humanistic concerns are inseparable from technical advancement, and a new 4IR curriculum will need to reduce the divisions between humanities and STEM to create a more integrated system of education which can explore the newly emerging conceptions of self and identity within the 4IR, including discussions of autonomy, free will, and genetic vs. social determinism. The changing nature of social relations and interactions—social media, obligations to identity groups, society, nation and world needs to be central in the 4IR curriculum as all of these identities and loyalties are shifting rapidly due to increased globalization.

More than ever, higher education in the 4IR age must develop the capacity not just for analyzing and breaking a technical or scientific problem into its constituent parts, but also must emphasize the interconnections between each scientific problem across global scales and interrelations between physical, chemical, biological and economic dimensions of a problem. As one author has put it, "there is a single planetary technical system" in which globally scaled markets enable "hundreds of thousands of transactions and information exchanges take place at the speed of light within the space of a microsecond."[52] This speed can cause volatility and chaos in financial systems, and similar analogs of interconnected complex systems exist in the realms of marine ecology, forest conservation, global

[50] Petar Jandric, "From Anthropocentric Humanism to Critical Posthumanism in Digital Education," in *Learning in the Age of Digital Reason* (Rotterdam, Sense Publishers, 2017), 195–210.

[51] Donna Haraway, "A Cyborg Manifesto: Science, Technology, and Specialist-Feminism in the Late Twentieth Century," in *The Cybercultures Reader*, eds. David Bell and Barbara M. Kennedy, (London: Routledge, 2000), 291–324.

[52] Peters, "Technological Unemployment," 36–37.

climate and the impacts of extinctions on the biosphere, to name a few examples. In all of these systems the rapidity of responses to the system and the larger network of interconnections can easily result in exponential responses to small perturbations, and the 4IR curriculum needs to train students to recognize and help manage the proliferating numbers of exponentially responding and interconnected systems.

New Sequencing of Education to Renew Skills

In addition to the more reflective residential education settings described above, the rapid pace of change within the 4IR will require rapid expansion of existing initiatives for updating skills after graduation and reconnecting within older workers in campus environments. Within scientific and technical education, we will need to educate and reeducate students to help develop and shape the use of today's most rapidly emerging technologies. Pathways for students to reengage with their institutions after graduation will become imperative and will provide both updated skills to workers and a new channel for younger students (and faculty) to engage with the rapidly changing realities within the industrial and corporate sectors. One innovative initiative exploring new sequencing of higher education is the Stanford2025 project, which envisions several mechanisms whereby students can extend their education over longer timeframes. One model is the "open loop university" where students can experience six years of higher education over their entire adult careers that can allow them to blend their learning with life experience and provide value to the campus by returning as expert practitioners over several intervals—enabling students to refresh their skills while interacting with the campus community. Another model known as the axis flip prioritizes skill development and competency training over content and disciplinary topics, requiring new methods of assessment and a degree known as a skill-print that students would constantly renew and extend through their careers.[53]

The hallmark of the 4IR is exponential growth and rapid change, which gives the curriculum an imperative to update content on an unprecedented frequency to match the rapid tempo of scientific and technological advances. A more responsive curriculum of this sort places an extremely high premium on faculty development and curriculum renewal, as well as the mandate to develop students who can think and reinvent themselves within the changing

[53] Stanford2025, "Learning and Living at Stanford – An Exploration of Undergraduate Experiences in the Future," June 1, 2013, http://www.stanford2025.com/.

world they will graduate into. Within future universities and colleges, both students and faculty will never be done with their educations, but instead must engage constantly with their colleagues and outside experts to frequently renew and update their skills. To enable faculty to maintain expertise based on the latest discoveries and technologies, more proactive and creative forms of faculty development will also be required.The 4IR campus must become a constantly renewing collaborative hub of activity to maintain itself within the fast-paced environment of the future.

Conclusion

The first three industrial revolutions provided evidence for the profound shifts in society, the economy and education which resulted in a proliferation of curricular innovation and the establishment of new educational institutions. As in the previous three industrial revolutions, the most profound effects of the 4IR on our society will not be realized for many decades. Unlike previous industrial revolutions, however, the 4IR features the impacts of several compounding exponential technologies which all share the capacity for rapid increases in scale and reductions of cost. This rapidity of advance in technologies demands a more proactive response from the educational sector than the more gradual societal evolution and subsequent response from educational institutions in earlier industrial revolutions.

The impacts of the emerging 4IR technology in economic and environmental terms alone will require a drastic reconsideration of the curriculum within higher education to enable students both to comprehend the individual technologies in detail and to be able to thoughtfully analyze and predict the evolution of networked systems of technology, the environment and sociopolitical systems. The dynamic responses with networked systems and exponential feedback effects will amplify the pace of change, as has already been seen in the context of global climate change and in many other physical and biological contexts. The 4IR STEM curriculum will need to focus on emerging technologies—robotics, AI, IoT, nanomaterials, genomics and biotech—to provide a workforce not only capable of developing new applications and products, but also capable of interpreting the effects of these technologies on society and using their training to provide sustainable and ethical uses of science and technology. More than any particular content area, curriculum needs to help students develop the capacity for ethical reasoning, for awareness of societal and human impacts,

and to be able to comprehend the impacts of 4IR technologies on people, so they are trained to not only increase our material prosperity but also to improve our social and cultural fabric. From strictly economic terms, students who are capable of creative insights, collaborating in diverse teams, and navigating through global cultural differences will be at an advantage in a workplace where the meaning of skills will become more of interpreting rapidly changing information and being able to work with experts and stakeholders toward common understanding of the benefits of sustainable development. While earlier industrial revolutions have prioritized some of the raw materials needed to fuel their factories or cities—placing a premium on capital based in physical resources such as land, water power, coal, oil and wood—the 4IR will place a premium on intellectual capital and in capacity for collective thought. Students who are able to learn in residential environments with diverse colleagues and develop solutions together in teams will be well trained for the types of tasks that will be asked of them in the 4IR. Our colleges and universities owe it to these students and our future to develop more interactive forms of pedagogy at all levels and to embrace a curriculum that stresses perspectives from multiple disciplinary and cultural perspectives over static swathes of disciplinary "content." Many of the emerging liberal arts institutions in the United States and Asia and new types of CTE curricula are providing useful examples of how to implement this new model of 4IR higher education. Higher education needs to recognize the necessity of adapting and scaling up these new 4IR forms of education rapidly to assure the sustainability of our environment and economy, as well as to sustain the relevance of higher education as a responsive and vital component of society. Taken together, these new forms of 4IR education will prepare both students and faculty for leadership roles in a world of rapidly accelerating change, with a curriculum that develops both technical mastery and a deep awareness of ethical responsibility toward the human condition.

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