Chapter 13
Looking Back, Looking Forward

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Abstract In the concluding chapter of this book, we explain how the reported research works are aligned with the current developments in higher education: the demands for developing knowledge workers due to the advent of knowledge society, the research evidence culled from years of research in learning sciences that inform effective ways of learning, and the emerging trend of leveraging technologies to transform education. Looking forward, we identify two emerging trends of research direction, integrating neuroscience and cognitive neuroscience in learning, and harnessing the power of machine learning and analytics.

Keywords Conclusion · Transforming higher education · Science of learning · Learning analytics

13.1 Introduction

This book is motivated and inspired to be a record of an institutional approach to transforming teaching and learning in higher education through research and development (see Chap. 1). The various chapters in this book document efforts from our initial foray into this area of work. In this concluding chapter, we will like to take a step back to explore how the works reported in this book fit into the broader developments in higher education and provide a vision on where we can move on from the current state of work.

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13.2 Transformation of Teaching and Learning in Higher Education—Fitting into the Broader Trends

13.2.1 Redefining Scholarly Work

The research studies reported here are aligned to the scholarship of teaching and learning, which was first suggested by Boyer (1990) in his seminal book "Scholarship Reconsidered". Boyer's work provides a new perspective to the conundrum of teaching versus research debate through the expanded and holistic view about the academic scholarship. According to Boyer, besides the scholarship of discovery (the traditional notion of research), scholarship of teaching, scholarship of integration and scholarship of application are other aspects of scholarly work. To achieve excellence in scholarship, these scholarly works can be assessed with the same set of generic standards (Glassick, Huber, & Maeroff, 1997): stating clear goals and objectives for the work, showing adequate preparation for the work (e.g. knowing the field, and bringing appropriate skills and resources), applying appropriate methods towards achieving the goals, presenting the findings effectively, and engaging in critical reflection of the work.

The main content chapters in this book are devoted to investigations that aim at improving teaching or students' learning in higher education. For example, the scholarship of integration is demonstrated in Chap. 2 through a systematic review of the literature on the scholarship of teaching and learning, thus providing an overall recommendation from the research and identifying areas that need further exploration. Scholarship of application is illustrated through a short intervention to promote students' growth mindset as seen in Chap. 4.

Shulman (1999) further qualified that a piece of scholarly work should be made public so that there is an opportunity for peer review and critique, and for other scholars to build on the work. This edited book does precisely that by sharing our emerging work in the scholarship of teaching and learning within the research community, inviting scholarly critique and furthering the advancement of knowledge. The publication of these works also allows us to share ideas that aim at advancing teaching and learning practices in higher education. As suggested in Chap. 1, we take an integrative approach that involves researchers from multiple disciplines and traverse the theory-practice nexus by exploring a range of work closer to basic research to more applied research. Overall, the intention is not just focusing on the scholarship of teaching and learning, but the range of scholarly works proposed by Boyer (1990).

13.2.2 New Demands and New Goals for Higher Education

The world we live in is experiencing dynamic changes. In fact, the writing is on the wall when Peter Drucker (1959), a management guru, prophesized the need for

knowledge workers in the twenty-first century. Today, we are experiencing the fourth industrial revolution (Schwab, 2016) where the power of computing intelligence is leveraged in many aspects of lives and the demand for the knowledge worker is intensifying. In this context, new graduates from higher education are facing a rapidly changing landscape.

First, given the rate of change and the power of computing, many job processes will be automated and replaced by machines. Cann (2018), a public engagement officer from the World Economic Forum, opined that machine can do more tasks than humans by 2025. Second, the "half-life" of knowledge is decreasing rapidly. The Ecosperity conference (2018), which congregated experts from various fields to study megatrends in the world to shape the future, produced a book publication which reported that nearly 50% of subject knowledge learnt during the first year of a 4-year technical degree will be outdated by the time a student graduates. The rapid generation of new knowledge leads to another issue: there is a huge divide between the haves and have nots. People who can innovate with their intellectual capital will have the tenacity to face the challenge of rapid changes, but not those without these resources; consequently, the gulf between the rich and the poor will widen at a faster rate. Third, in the same report by Ecosperity (2018), it was suggested that the three-stage life model (Education, Work and Retirement) is evolving. The younger generation now has a more mashed up phases in life where learning is featured at various stages in life as they explore different types of jobs. In the past, we used to frown on people who change jobs every few years, but it seems to be getting more common for the youths to explore different options in life. In short, the concept of lifetime *employment* is changed to lifelong *employability*. Finally, the skill sets and competencies for graduates are changing. The Future of Jobs, a report by World Economic Forum (2016), stated that the top five skills needed by workforce in 2020 include complex problem-solving skills, social skills (e.g. emotional intelligence, coordinating with others), process skills (e.g. active listening, critical thinking, monitoring self and others), systems skills (e.g. systems analysis, judgement and decision-making) and cognitive abilities (e.g. cognitive flexibility, creativity). These are often labelled as the "soft skills", which is a misnomer since they can be harder skills to develop.

All these changes point to the fact that intellectual capital, more than physical capital, will represent the critical factor of survival for an economy. The demand for highly skilled workers has increased, while the demand for workers with less education and lower skills has decreased. In addition, the new graduates not only need to possess deep disciplinary content knowledge, but also develop critical soft skills. Finally, given the rapidly changing landscape, new graduates need to learn to become knowledge workers who can solve problems creatively, create new ideas of values, be self-directed in learning and learn how to learn new knowledge and skills, all these points towards the need to explore new ways of learning.

In this book, Chap. 4 illustrates an attempt to influence students' growth mindset. Based on Dweck's (2006) work, a growth mindset is strongly related to students' motivation in learning. Chapter 5 examines how adult learners (teachers) learn in a professional learning community that uses knowledge building pedagogy, rather than learning through formal training courses. By sharing challenges and differing

views about how to guide students, the teachers co-construct pedagogical decisions to guide their students and learn about the enactment of knowledge building principles. These cases illustrate how we help learners develop competencies that are considered twenty-first-century skills.

13.2.3 Implications of Advances in Learning Sciences for Teaching in Higher Education

Teaching in higher education tends to follow the standard lecture-tutorial method that focuses on the transfer of knowledge. However, advances in learning sciences are shedding light on the learning processes and conditions that are likely to enhance the effectiveness of learning. In the latest study report (National Academies of Sciences, Engineering, & Medicine, 2018), culminates from consensus among learning scientists, some key insights were shared: (1) there is a strong cultural influence that shapes individual's experiences and how individuals learn from early stages in life; cultural influence can sanction the content of learning as well as the appropriate approaches to learning; (2) learning changes how our brains are wired (forming and pruning of neural connections) and conversely, our brain develops throughout our lives to affect learning (our brain continues to adapt to changes in different life stages including natural memory decline as we age); (3) developing mental models helps one to retain knowledge and apply knowledge in a flexible way; on the other hand, existing mental models can create biases about how we attend to new information; (4) motivation is critical to learning as individuals need to value what they are asked to do as learning tasks.

This collective wisdom culled from studies in learning sciences suggests that to achieve effective learning, acquisition of knowledge is but one small part of learning. Sfard (1998) explicated on the metaphor of *learning by acquisition* and *learning by participation*. In short, learning by acquisition treats knowledge as entities that can be transferred from the more knowledgeable to the less, while learning by participation entails interacting with others in a community with shared goals and developing expertise through doing and dialoguing. Sfard suggested that both are necessary. Relating to the learning sciences consensus report (National Academies of Sciences, Engineering, & Medicine, 2018), learning by participation embraces the cultural influence in learning as it treats learning as a re-culturation process; it also addresses the motivation needs of learning because what an individual chooses to participate in a community is often what the person values. Researchers working on learning as knowledge creation (Paavola & Hakkarainen, 2005) further suggest the importance of creating knowledge artefacts. These knowledge artefacts serve as a mediating tool for learning, as well as a record of advancement in knowledge within a community.

Several chapters in this book showcase studies that are built on the foundation of learning sciences. Chapter 5 reports a participatory approach to learning among a group of practicing teachers. In Chap. 9, knowledge building approach was used for

learning among graduate students, where the students collaborate and co-construct their understanding of key concepts and issues, instead of merely going through lectures. Chapter 3 explores language learning and relates to neuroimaging evidence for the bilingual brain. Chapter 4 focuses on motivational aspect of learning.

13.2.4 Technology-Enhanced Learning

The integration of Information and Communication Technologies (ICT) into teaching and learning in higher education has become a common practice; many hope to revolutionize higher education in the twenty-first century (Oliver, 2002). A common approach is to use learning management systems (LMS) to facilitate and support a variety of course delivery functions, such as course administration, sharing of course materials, tracking online behaviours and administrating short tests (Chung, Pasquini, & Koh, 2013; Young, 2013).

However, "[s]imply capitalizing on new technology is not enough; the new models must use these tools and services to engage students on a deeper level" (Johnson et al., 2013, p. 9). Integrating ICT into a classroom requires a systemic change and holistic approach, including changing the appraisal systems for the faculty, providing faculty training and changing attitudes towards the use of technologies among academics. The common practice of using LMS reflects that universities are more concerned with administrative and managerial roles of technologies (Selwyn, 2007). Pedagogical applications of ICT into teaching and learning are critical. For example, we could use computers as cognitive tools to support students in thinking (Tan, 2019) rather than using computers as a tutor. Tan (2014) advocates using ICT such as computer-supported collaborative learning to support knowledge creation. It involves students in dialogic interactions while they create knowledge artefacts. Such an approach aligns with the development of students' innovative disposition and epistemic agency to explore new perspectives, propose new ideas and experiment with their ideas. It is a more promising approach that could help prepare students of higher education to meet the demand of the knowledge-based economy.

In this book, several chapters were devoted to exploring the use of technologies in higher education. There is a conscious attempt to avoid simply using computers as a tutor for transferring knowledge. Chapter 6, for example, detailed the journey of pedagogical changes supported by technologies. Several key terms underpinned these transformations: responsive to students' needs, promoting interactions and designing for learning. All these allude to foregrounding pedagogies and students' learning. Chapter 8 describes a team-based approach, which privileges self-directed learning and learning in a group, underpinned by the inter-dependence principle of cooperative learning (Johnson & Johnson, 2009). Technologies are used to support learning, as well as analysing students' data to extract key engagement behaviours that relate to better performance. Chapter 9 illustrates using technologies to support knowledge creation approach. Similar to Chap. 8, technologies are used to support

collaborative learning in multiple ways—both online collaboration and analytics to identify promising ideas.

Now that we have revealed how our research works are shaped by the megatrends facing higher education, how can we continue with our efforts to contribute to the broader higher education community in shaping our future?

13.3 Looking Forward

To iterate, this book illustrates an institutional approach to transforming teaching and learning into higher education through research and development. As such, the studies are sampled from the same institution. We acknowledge the values of sampling studies and sharing experiences across institutions and countries, which can be considered in future edition of similar books.

Looking forward, we identified two areas of research and developmental works that are promising in transforming teaching and learning in higher education: educational neuroscience and leveraging the power of artificial intelligence, machine learning and analytics.

Traditionally, research devoted to understanding learning has taken place in many different disciplines such as education, psychology, cognitive science and technology. In the 1990s, researchers began to recognize that understanding learning in different contexts and forms require multiple approaches that span these disciplines. A group of researchers from various disciplines came together to create a new field of study called the *Learning Sciences*. Their main goal is to study learning as it happens in real-world situations, with the ultimate goal of designing learning environments for more effective learning. In short, they are aiming at creating real impact in classrooms. As neuroscience research gains traction in the past two decades, researchers began to explore how the knowledge generated can contribute to understanding learning. The term *Science of Learning* is used increasingly to reflect this trend. It is a multidisciplinary approach, with the ultimate goal of optimizing learning for all. To translate research in neuroscience into pedagogical applications in classrooms is, by no means an easy task. Internationally, researchers recognize this as a challenge. In fact, there has been criticism and caution against the over-enthusiasm of educational neuroscience where expectations exceed the limitations of current basic science resulting in "a bridge too far" (Bruer, 1997, 2006) and "a bridge astray" (Dougherty & Robey, 2018). Thus, a thoughtful and dynamic multi-phased and multidisciplinary approach would be needed to consider various aspects from the learning sciences, as well as how we can optimize the condition to learn (as in brain health) is timely.

13.3.1 Connecting Educators and Learners to Harness Brain Knowledge and Cognitive Neuroscientists to Educational Research

Introducing neuroscience to education has been a journey wrought with challenges but great enthusiasm. This process has been stimulated with the advancement of technology in non-invasive neuroimaging techniques that allows us to "see" the living brain in vivo to better understand its function and networks. This gave rise to an interdisciplinary research field of educational neuroscience. This Science of Learning seeks to translate research findings on neural mechanisms of learning to educational practice and policy, and to understand its effects on the brain (Thomas, Ansari, & Knowland, 2019). However, as cognitive neuroscience research is not designed to answer classroom questions directly or from the surface (but rather through several steps of translation), many are dismayed that immediate answers cannot be gleaned from neuroscience findings. This is a result of mismatched expectations. Just as in the early days of medicine, where there is a lack of technology to understand underlying mechanisms, many clinical practitioners relied on clinical lore and common practice, rather than evidence-based practice. Similarly, knowledge about brain sciences could provide educators better understanding to tweak their pedagogy. This may allow the development of more precise methods to help learners improve learning outcomes and establish more evidence-based intervention in educational practice. On the other hand, it is important to know what kind of brain knowledge that educators need and at what level. Oversimplifying complex information about the brain may result in falsehoods known as neuromyths that perpetuate popular neuroscience in the media and on the Internet. Thus, a systematic model is presented at CRADLE to help scope and craft the dynamic journey to translate cognitive neuroscience to education and vice versa.

Chapter 3 illustrates this effort where scholars from cognitive neuroscience work collaboratively with educational researchers to create an impact on bilingual learning, a critical educational approach in the context of Singapore. What is reported in Chap. 3, however, is only a glimpse into a broader research agenda. Moving forward, we have proposed to adopt a more holistic view to translate the upstream science of learning research findings to downstream classroom impact. As mentioned in our introduction, our research is guided by a translational trajectory that traverses the nexus between basic and applied research (see Fig. 13.1).

Working in the science of learning and learning sciences nexus is critical where the former provides the science while the latter informs pedagogical redesign and implementations. It is a two-way process; as we work with classrooms, we could generate new insights that motivate new research among the neuroscientists. This is important in creating impactful change that translates laboratory findings into classroom practices. We need to integrate expertise in both the science of learning and learning sciences and think of ways to develop a community of researchers integrating Science of Learning and Learning Sciences.

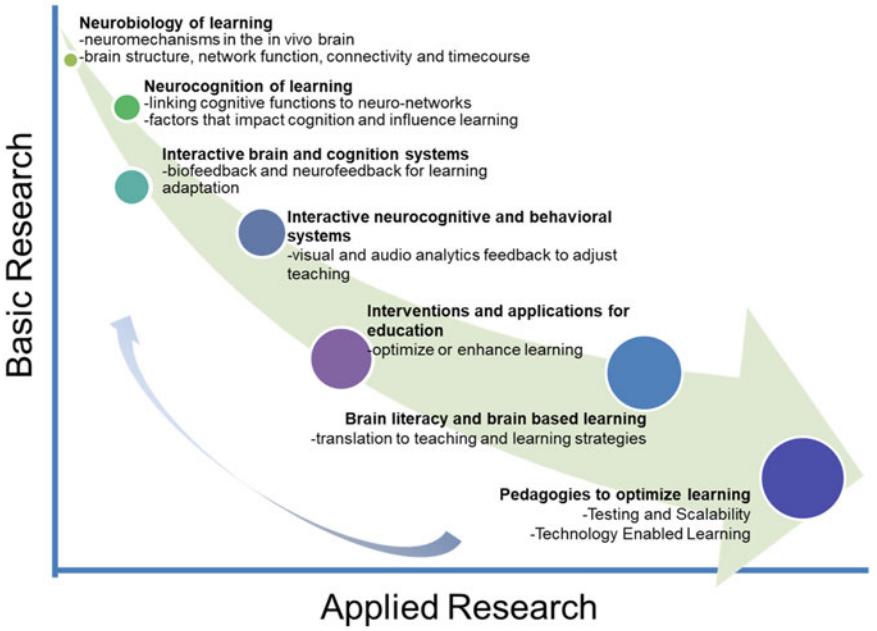

Fig. 13.1 Traversing basic and applied research nexus for neuroscience and learning

Currently, we are working as a boundary agent and facilitator to link up researchers from various schools and departments, including the Schools of Social Sciences, Humanities, Engineering, Medicine, and Educational and Research units in our university such as the Centre for Research in Child Development, and Centre for Research in Pedagogical Practices, and Ageing Research Institute for Society and Education. We see our role as a connector to help educational researchers to harness the knowledge about the brain in developing their best practices to be tested, as well as helping cognitive neuroscientists to reformulate their questions to address challenges faced by educators. This approach is promising in that by having a multidisciplinary team of researchers, we can engage in interdisciplinary studies that could ultimately create transdisciplinary knowledge.

Another advantage of coordinating research across the university is that we are now able to contribute to research for lifelong learning. For example, some researchers have embarked on research to study factors that influence the development in early childhood, focusing on the development of executive functioning, self-regulation, language and mathematical reasoning in children. We have researchers working with K-12 students, for example, helping learners with persistent low math achievement, identify and study the neuro-correlates of mathematics learning, and design games to help them learn better. This can improve academic performance for disadvantaged learners. More recently, we are embarking on research examining whether cognitive flexibility can be enhanced through cognitive training and if

the increase of cognitive flexibility could improve adaptability during transition life stages. Another group of researchers is looking at students transitioning from adolescent to adults, to develop sustained interest in learning, with the ultimate goal of developing a joy of learning, passion and grit in our students. Yet, another group is studying learning for adult learners, as well as mature adults. There are ongoing projects on developing literacy among adult learners with the ultimate goal of enhancing their employability.

Embarking on the science of learning research for lifelong learning is strategic for a few reasons. First, there is far fewer science of learning research with adult learners compared with research on young children. Second, it will give us better ideas about learning at different stages of maturity and constraints. Knowing the conditions to maximize learning at different stages of our lives help to maximize human potential. It is aligned to the current emphasis on lifelong learning.

13.3.2 Machine Learning and Analytics

With the advancement in data science and analytics, colleges and universities worldwide are leveraging business intelligence and analytics for data-driven decision-making (Daniel, 2015), which is timely in the context of increasing competition for students, greater accountability and increasing operational challenges. Renowned universities are setting up institutional analytics units that play the strategic roles of assessing and evaluating academic programmes, sharing best practices, generating accountability reports, and managing organizational changes. The main advantage of institutional analytics is the centralization and integration of data sources and reporting systems, which moderates the inefficient processes and practices such as duplication of data, storage of information in silo, ad hoc request for information, duplication of analysis and labour-intensive manual analysis.

Besides the use of business analytics for institutional decision-making, analytics can also be used to support learning. One of the trends is the addition of analytics packages in Learning Management Systems (LMS) such as Blackboard Learn (Blackboard Inc., 1997) and the Moodle (2002) platforms. Content-delivery platforms that support Massive Open Online Courses or MOOCs such as edX (edX Inc., 2012) and Coursera (Coursera Inc., 2012) also have analytics embedded. The analytics in these platforms provide a suite of visualization and analytical tools that provide a macro view of learners' behaviours in the courses or lessons, for example, the login time, the duration of access and the performance on quizzes. With deeper analyses, some systems are able to provide predictive analytics that could provide information for early intervention of at-risk students. Chapters 8, 9 and 10 in this book illustrate some of our efforts in using analytics to inform learning.

Moving forward, we are exploring the use of data from different modalities and sources to inform different aspects of learning. In one study (Tan, 2018), we collected multimodal data of teachers teaching science in secondary schools (eye-tracking

device, a microphone and multiple video cameras). These sources of data are integrated, followed by a multi-layer analysis to provide insights into the teaching practices. From the data, we extracted segments of videos and engaged the teachers in video-stimulated reflections. We are able to distil what teachers notice in their classrooms when they are teaching, how they interpret and make sense of these events, how they responded to these events and how they can improve on their teaching practices in the future. Such studies provide evidence that prior knowledge and experiences of a teacher, together with visual cues in the classroom, can affect how a teacher makes a decision about their talks or actions in the classrooms. Understanding how teachers make a moment-to-moment decision will have a real impact on their teaching and consequently, on students' learning in classrooms. Another study (Chua, Dauwels, & Tan, 2019) focuses on the development of technologies to collect and analyse data as students are interacting in group discussions. The ultimate goal is to quantify the dynamics of collaborative learning processes and support collaborative learning in an automated fashion.

Another capstone study (Tan, Tan, & Pua, 2019) harnesses physiological data to study emotions in learning. This study aims to identify instructional events that generated anxiety when science teachers are teaching. The stress responses of these teachers are monitored by wearables to capture their mean heart rates, mean heart rate inter-beat (RR) intervals and skin conductance responses; a combination of these data is used to detect stressful events felt by the teachers, and these are verified through reviewing of videos by the teachers. Initial analyses of data suggest that teachers are stressed when facilitating discussion, teaching unfamiliar content, facing students' interruptions during teaching and having to complete instruction within some time constraints. Continuing with this line of research, we will identify ways of overcoming or reducing stress during teaching and helping teachers to cope with stressful events in classrooms.

13.4 Conclusion

This book has provided a sampling of the efforts at the Centre of Research and Development in Learning (CRADLE) over the initial 4 years. We have established a foundation developed with a framework from the Mind, Brain and Education tradition merging disciplines of Education, Neuroscience and Psychology, integrating technology and the Learning Sciences. This framework allows us to start addressing the main key research questions of optimizing learning outcomes through the pursuit of research excellence. Through these efforts in building research capacity for an emerging field of the Science of Learning, we envision our research efforts will eventually empower and transform learners in higher education and lifelong learning. We suggest universities could consider setting up research centres or equivalent units that serve as an activity and technology incubator for researching and transforming learning in higher education, and enhance learning by developing effective technologies, mindful learning environments and motivating activity designs that are supported by

empirical research. To achieve these goals, the research centres need to engage with learners, professionals and the teaching community to identify research needs, support development opportunities and diffuse research outcomes. Such centres could lead innovative interdisciplinary research founded on the Science of Learning and take a multidisciplinary approach to foster interdisciplinary research and seek to develop a transdisciplinary outcome for the Science of Learning. We believe that transformative innovation can happen at the nexus of these different fields and the relevant research strands can provide synergies between these disciplines in the hopes that such collaborative efforts may give way to a New Science of Learning in the coming years.

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