Seng Chee Tan
Shen-Hsing Annabel Chen *Editors*

Transforming Teaching and Learning in Higher Education

A Chronicle of Research and Development in a Singaporean Context

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This book is dedicated to late Professor Sing Kong Lee

—a horticulturist, a passionate educator, and a visionary leader extraordinaire

Preface

In 2015, the late Professor Sing Kong Lee set up the Centre for Research and Development in Learning, or CRADLE in short, in the Nanyang Technological University (NTU), Singapore. Previously served as the Director of the National Institute of Education from 2006 to 2014, he was familiar with educational transformation in the K–12 sector. Still burning with passion for education, he had the vision of transforming the quality of teaching and learning in the university. He became the natural choice to be the first director of CRADLE, while he also took on several other portfolios in the university, including the Vice President (Education Strategies) of NTU.

Professor Lee envisioned CRADLE to be the seed of educational innovation, playing several strategic roles such as

- **S**erving as an activity and technology incubator for researching and transforming learning in higher education
- **E**nhancing learning by developing effective technologies and mindful learning environment and activity designs supported by empirical research
- **E**ngaging with students, professionals, and the teaching community to identify research needs, support development opportunities, and diffuse research outcomes
- **D**eveloping integrative and holistic models of assessment that measure learning anywhere, anytime, and without compromising rigor, objectivity, or integrity.

Under Prof. Lee's leadership, seed funding was set up to support initial exploration into research and development to transform teaching and learning in the university. CRADLE also collaborates with the Institute of Adult Learning, Singapore, and with its existing link with the National Institute of Education, a lifelong learning research agenda in Singapore became possible. Beyond the local shore, CRADLE has collaboration with Johns Hopkins University, Cambridge University, and Western University, Ontario.

A sudden heart attack took away Prof. Lee's life in 2017, but his legacy of passion for education lives on. We, the editors of this book, had the privilege of working with the late Prof. Lee. We are also fortunate to have the continual support and guidance from eminent professors in NTU, especially Prof. Kim Yong Lam, Prof. Timothy White, and Prof. Theng Yin Leng.

This book is a chronicle of reports, borne out of our initial efforts in CRADLE. While the contexts of the studies are inevitably local, the research studies are underpinned by theories and principles developed by international researchers, thus the intended contribution is to the worldwide research communities, including the scholarship of teaching and learning and learning sciences.

We hope you will find the reports in this book useful, and our doors are always open to like-minded researchers who are keen to transform education in universities. We welcome your collaboration.

Editors
Singapore, Singapore
Seng Chee Tan
Shen-Hsing Annabel Chen

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Editors and Contributors

About the Editors

Seng Chee Tan was among the pioneers who helped to set up the Centre for Research and Development in Learning (CRADLE) at Nanyang Technological University (NTU), Singapore. He was a Deputy Director of CRADLE@NTU from 2015 to 2016 and Acting Co-director from 2017 to 2019. He is currently the Associate Dean (Higher Degrees) of the Graduate Studies & Professional Learning at the National Institute of Education (NIE). Dr. Tan received his Ph.D. in Instructional Systems from Pennsylvania State University and joined NIE, NTU in 2000. Prior to his appointment at CRADLE, he served in a number of roles promoting the use of ICT in education, including as Head of the Learning Sciences and Technologies academic group at NIE, Singapore, and as Assistant Director of the Educational Technology Division, Ministry of Education. His research interests include Computer-Supported Collaborative Learning, knowledge creation in education, and teacher education. He is the first editor of the book "Knowledge Creation in Education" (Springer), published in 2014 and the first author of the book "Pushing the frontier: A cohesive system-wide approach to integrating ICT into education" (Springer), published in 2017.

Shen-Hsing Annabel Chen is a Professor of Psychology at the College of Humanities, Arts and Social Sciences and holds joint appointments at LKC Medicine and the NIE. She is a clinical neuropsychologist (licensed in Clinical Psychology, USA; Singapore Registry of Psychologists) by training and has worked with both adult and child populations. She received her doctorate in Clinical Rehabilitation Psychology from Purdue University in Indianapolis and completed her clinical psychology internship in Behavioral Medicine and Psychiatry at West Virginia University School of Medicine. She pursued her postdoctoral residency in Clinical Neuropsychology in Neurology at the Medical College of Wisconsin and worked as a postdoctoral research affiliate at the Lucas MRS/I Center of Radiology at Stanford University School of Medicine. She was an Assistant Professor at

National Taiwan University's Clinical Psychology Graduate Program before joining NTU in 2008. She served as the Associate Chair of Research at the School of Humanities and Social Sciences and is currently the Acting Director of CRADLE. Her research interests include higher cognition in the cerebellum, ageing neuroscience, deception neuroscience and education neuroscience.

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Commonly Used Acronyms

3Ps model	Bigg's Presage, Process and Product model
ANOVA	Analysis of Variance
ARS	Academic Resilience Scale
CALL	Computer-assisted Language Learning
CHAT	Cultural Historical Activity Theory
CoP	Communities of Practice
CRADLE	Centre for Research and Development in Learning, Nanyang Technological University, Singapore
CSCL	Computer-supported Collaborative Learning
DOS	Department of Statistics
EFA	Exploratory Factor Analysis
FGD	Focus-group Discussion
HEI	Higher Education Institute
I^2A	Idea Identification and Analysis methodology
ICT	Information and Communication Technologies
IT	Information Technologies
IHL	Institutes of Higher Learning
iRA	Individual Readiness Assessment
JMD	Just Manageable Differences
K12	Kindergarten to 12^{th} Grade
KB	Knowledge Building
KF	Knowledge Forum
LA	Learning Analytics
LAMS	Learning Activity Management System
LMS	Learning Management System
MCQ	Multiple-choice Question
MOE	Ministry of Education, Singapore
MOOC	Massive Open Online Course
NTU	Nanyang Technological University, Singapore
PLC	Professional Learning Community

RAP	Readiness Assurance Process
SAMR	Substitution, Augmentation, Modification, Redefinition—Model of Technological Transformation by Puentedura
SDL-TBL	Self-directed Team-based Learning
SoED	Scholarship of Educational Development
SoTL	Scholarship of Teaching and Learning
TBL	Team-based Learning
TEL	Technology-enhanced Learning
tRA	Team Readiness Assessment

Chapter 1
Introduction

Seng Chee Tan and Shen-Hsing Annabel Chen

Abstract This is the introductory chapter of this book. It explains the genesis of this book, which is the product of a transformation effort to enhance the quality of teaching and learning in a university. It is aligned to the recent worldwide efforts in expanding the notion of scholarly works in a university, specifically the Scholarship of Teaching and Learning (SoTL). At the same time, it attempts to integrate the latest developments in neuroscience and learning sciences to inform research. A multidisciplinary framework that integrates neuroscience, education, technology and psychology was developed as the initial effort towards the ultimate goal of creating a transdisciplinary science of learning. Consistent with this framework is also the multiple perspectives on how learning is defined. This chapter also provides an introduction to the subsequent chapters in this book.

Keywords Introduction · Scholarship of teaching and learning · Science of learning

This book is a chronicle of research reports that are fruits of our labour deriving from an institutional approach of transforming teaching and learning in higher education through research and development. It is written for researchers and educators who are working on institutional transformation effort in higher education, particularly in the area of innovating teaching and learning approaches, and using an evidence-based approach for change. It aims to illustrate an integrative approach within an institution, facilitated and coordinated by a centre. A research and development hub, known as the Centre for Research and Development (CRADLE) has been operational in the Nanyang Technological University, Singapore, since 2015. In this introduction chapter, we present our transformational model that aims at improving teaching and learning at higher education and provides an introduction to the subsequent chapters in this book.

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1.1 Context of Teaching and Learning Transformation at the University Level

In the era of the knowledge-based economy, ubiquitous connectivity and knowledge resources and the demand for knowledge workers are intensifying the need for university graduates to go beyond merely acquiring existing knowledge, but to also have the capacity to synthesize and apply new information and create new knowledge, ideas and values. This favours self-directed, active learners, and calls for innovation in instructional approaches. In this regard, research-intensive universities worldwide are intensifying their transformation in educational approaches (Gurung, Ansburg, Alexander, Lawrence, & Johnson, 2008; Malfroy & Willis, 2018; Simmons, 2016).

What does transformation mean? The term *transformation* connotes a radical change in the appearance or the nature of something. As an example, in the context of integration of technology in education, the SAMR (Substitution, Augmentation, Modification, Redefinition) model (Puentedura, 2012) provides a good illustration of transformation. Puentedura (2012) suggested that technology can be used to substitute a traditional tool (e.g. using whiteboard instead of a blackboard), or to augment old technology (e.g. using PowerPoint that provides more functions like animations, instead of using transparency with an overhead projector). In these cases, technologies are not used in a transformative way but are tools for functional enhancements. It is regarded as transformative only when there is a signification modification to the learning tasks (e.g. creating a concept map that crosslinks various topics) or to redefine how learning occurs (e.g. learners across countries engage in collaborative idea improvement or co-construct an essay through an online tool). In short, in the context of teaching and learning, transformation means going beyond a simple addition of instructional tools, or making a simple tweak to an instructional method. Instead, it means making a significant change in teaching and learning interactions or learning mechanisms that aims at improving students' learning.

In the context of higher education, the seed to transformation in teaching and learning can be traced to the development of Scholarship of Teaching and Learning (SoTL) that was attributed to the seminal work by Ernest Boyer (1990) (see Chap. 2). SoTL is "an emerging movement of scholarly thought and action that draws on the reciprocal relationship between teaching and learning at the post-secondary level." (Website of the Society of Teaching and Learning in Higher Education, n.d.). Various strategies for developing SoTL at the institutional level have been proposed, including a ground-up organic approach (Vithal, 2018), provision of learning and teaching grants (Malfroy & Willis, 2018), and supporting SoTL through a micro–meso–macro framework (Simmons, 2016).

Chapter 2 of this book provides a systematic review of SoTL publications in the past five years. Several key trends were noted by the author:

1. There are varying definitions and conceptions of SoTL; many are context-specific and are primarily focused on teaching and learning processes;
2. There is substantial diversity in SoTL methodologies; scholars are embracing different methodologies (e.g. quantitative and qualitative; mixed methods);

3. There is a variety of research topics on teaching and learning practices including strategies for faculty professional development, strategies focusing on improving student learning experience and outcomes and the instruments, tools and platforms for learning;
4. SoTL research has been applied in various disciplines, programmes and processes; there is increasing call for research in a multidisciplinary context, as well as stronger collaboration among researchers from different disciplines;
5. There is a clarion call for institutional support for SoTL research, including the importance of educational leadership and strategies to cultivating institutional culture conducive to SoTL research.

Several areas that deserve more attention were also suggested in Chap. 2:

1. Stronger theory–practice links in SoTL research;
2. Research on Technology-enhanced learning can be further explored;
3. Studies on technology-enhanced learning to be informed by learning theories or principles;
4. Promoting more multidisciplinary and collaborative research across disciplines.

1.2 A Working Model for Teaching and Learning Transformation in a University

The Nanyang Technological University (NTU) is a research-intensive comprehensive university in Singapore that comprises colleges of Engineering, Business, Science and Humanities, Arts and Social Sciences, Lee Kong Chian School of Medicine (jointly established with Imperial College London) and its Graduate College. It also houses autonomous institutes such as the National Institute of Education, Singapore and the S. Rajaratnam School of International Studies. In addition to its efforts in academic research, NTU also emphasizes innovation in teaching and learning. It has set up the Teaching, Learning and Pedagogical Division to support faculty professional development, as well as invested heavily in technology-enhanced learning. The establishment of the Centre for Research and Development (CRADLE) in 2015 aimed to further strengthen leadership in research into teaching and learning in higher education.

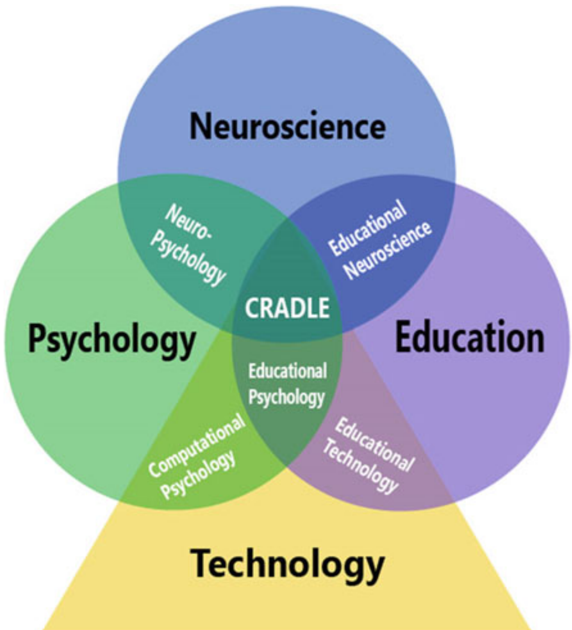
CRADLE aims to serve as the seed of innovation by (1) serving as an activity and technology incubator for researching and transforming learning in higher education; (2) enhancing learning through interdisciplinary research that translates into effective learning designs; (3) engaging with students, professionals and the teaching community to identify research needs, support development opportunities and diffuse research outcomes and (4) developing innovative assessment approaches including learning analytics to support effective learning.

The transformation approach by CRADLE is well aligned with the review and recommendations of SoTL presented in Chap. 2. For example, in Chap. 3, a multidisciplinary team of researchers works together to address a practical bilingual education problem by drawing on knowledge generated from cognitive, neuroscientific and linguistic research. Similarly, in Chap. 8, researchers from education, engineering and medical schools converged to develop a computational framework for modelling student engagement in a team-based learning ecosystem; it draws on principles of team-based learning and knowledge from the field of learning analytics and machine learning. It is also one that explored technology-enhanced learning.

In addition, CRADLE's transformative effort aims to expand beyond SoTL's usual territory, to include a wider area of research and development such as neurobiological studies on learning, development and deployment of learning analytics, and study on learning environments. In other words, beyond inquiry into teaching and learning in classrooms, the research agenda includes studies on other components in the entire learning ecosystem in an Institution of Higher Learning (IHL).

At the outset, CRADLE was set up to be a multidisciplinary research hub, integrating psychology, neuroscience, education and technology to develop theories that explain learning in all of its forms (Fig. 1.1). We take a multidisciplinary approach (integrating knowledge and skills from various disciplines) that fosters interdisciplinary research (researchers from various disciplines working on a common research problem) which seeks to develop a transdisciplinary outcome for the Science of Learning (gearing towards a new discipline of study called Science of Learning).

Fig. 1.1 Integrating multiple disciplines for the science of learning



While the ultimate goal of creating transdisciplinary knowledge is a long-shot, initial research efforts started with the interfaces between educational and psychology, or educational and technology, with increasing input from the neuroscience. Chapter 3 illustrates this effort where scholars from cognitive neuroscience work with educational researchers collaboratively to create an impact on bilingual learning, a critical educational approach in the context of Singapore. What is reported in Chap. 3 is only a glimpse into a broader research agenda, moving forward, we need to work at the nexus of basic to applied research to translate knowledge from cognitive neuroscience to classroom applications (see the Concluding chapter in this book).

CRADLE takes a multi-level perspective of learning (Fig. 1.2), starting with treating learning as a phenomenon that engages individuals in cognitive processes and neural changes (see Chap. 3). These changes due to learning often manifest themselves in behaviours, such as changes in the ability to answer a question or to perform a new skill. In many situations, learning involves interactions among individuals (e.g. dialogic interactions). Thus, how learners collaborate and how they learn through meaning making in a group setting is an important area of investigation (see Chaps. 5 and 8). Learning can also be investigated at an organizational level when an individual's behaviours or outcomes are aggregated and analysed. Such a normative approach is useful when building educational models that predict learners' behaviours so that proactive advice and guidance can be provided. With the advancement of networked technologies, learning can also transcend the boundary of physical space (classrooms), such that learners are connected in cyberspace. Online learning can be the main mode of interactions (such as Massive Open Online Courses), or it can complement face-to-face instructions (such as in flipped classrooms). Together,

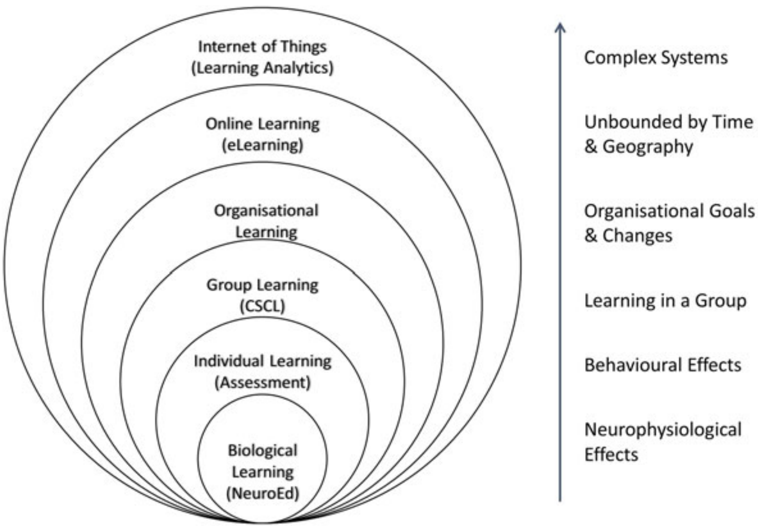


Fig. 1.2 Multi-level perspective of learning

the material environments and the online environments play critical roles in learning as they provide necessary resources for the learners, and conversely, learners' outcomes are also manifested as learning artefacts. In short, material artefacts mediate learning and provide valuable information about learning processes and outcomes.

With the framework and approaches to teaching and learning research explained above, several research projects were initiated, and findings from some of these projects are presented here. The next section introduces the chapters in this book; similar summaries can also be found in the abstract of each chapter.

1.3 Introduction to the Chapters in This Book

Building on the foundation of the Scholarship of Teaching and Learning (SoTL) research in the higher education context, Chap. 2 (A Systematic Review of Scholarship of Teaching and Learning Research in Higher Education Institutes from 2014 to 2019) reports a systematic review of SoTL research in the last five years. Through a review of 181 articles, this chapter reports the salient themes of research in SoTL, including (1) the conceptualization and framing of SoTL; (2) methodologies and approaches used in SoTL; (3) research focusing on teaching and learning strategies and tools; (4) SoTL research in specific disciplines and context and (5) Institutional support for SoTL.

The subsequent chapters in this book are presented in an order that roughly follows the multi-level of learning (Fig. 3), starting from individuals (the neurobiological perspective, to behavioural) to learning in a group (collaborative), to online learning and exploration of learning environments. They also represent research at different nexuses of various fields (Fig. 1.1), starting with neuroscience and education, psychology and education, technology and education and the learning environments.

Focusing on neurobiological and behavioural level of learning for individuals, Chap. 3, titled "The Impact of Bilingualism on Skills Development and Education", explores the impact of bilingualism on skills development and education through a systematic research framework. The authors started with reviewing and summarizing the findings from several studies that examined the impact of bilingualism on teaching and learning in the context of Singapore from different perspectives using a variety of methods, including surveys, behavioural assessment, neurocognitive tasks and neuroimaging techniques (e.g. functional magnetic resonance imaging). Next, they discussed the possible impact of bilingualism on early childhood education by considering various factors that might be associated with language learning and development. Following that, they reviewed existing neuroimaging evidence to outline how language and reading were represented in the "bilingual brain". Finally, they provided a glimpse into an ongoing project that employed a combination of multiple methods to investigate the impact of different script types on the neural reading networks for typical and atypical bilingual readers.

Still focusing on individuals and sitting at the nexus of psychology and education, Chap. 4 (A Preliminary Study on the Impact of a Brief Online Growth Mindset Intervention on University Students) reports a study on the use of an online growth mindset intervention (Dweck, 2006) to promote students' development in terms of cognitive, academic and behavioural skills. Research has shown that students' beliefs or mindset can affect how they interpret their academic performance and their subsequent actions. Helping students to approach mastery goals rather than performance goals can benefit the students (Dweck, 2006). This study examined whether a short online intervention can have positive effects on students. The results show that among the 120 university students who participated in this study, the group of participants who received the short intervention showed a significant increase in their growth mindset and a significant decrease in the fixed mindset. The students' mastery approach and academic resilience scores also improved significantly. These are indications of the positive impact of the intervention.

Chapter 5 (Negotiating Objects of Activity for Teacher Learning in a Professional Learning Community) extends the investigation of individual learning to collaborative learning in a community, which involves the social psychology of learning. This chapter reports a study focusing on teacher learning in an authentic context (within a school) through a Professional Learning Community (PLC). In this PLC, a community of teachers collaboratively engaged in critical inquiry to improve their teaching practices. This chapter uses Cultural Historical Activity Theory to analyse a case of a group of elementary school teachers working on lesson design using knowledge building pedagogy to enhance student learning. By examining the teachers' conversation, the authors show how the teachers navigate through the tensions and conflicts that challenged established pedagogical practices. Through the co-configuration of work activities in the PLC, the authors explicated how pedagogical decisions are constituted at the local level for classroom implementation.

Chapters 6–10 feature research at the nexus of technology and education as a review of SoTL (Chap. 2) shows that the use of technology in higher education could be explored further. Chapter 6 (Applying just manageable differences as a guiding principle for course transformations) examines changes to a course curriculum and methods. It showcased how university teachers refine a multidisciplinary science course by applying the principle of just manageable differences, which are incremental changes from one running of the course to the next to make learning increasingly meaningful to the students. Chapter 6 illustrates changes from teacher-centric to learner-centric approach, from a lower level to higher level learning objectives in Bloom's taxonomy, from face-to-face to incorporation of online components, and from individual learning to increasing social interactions.

Similar to Chaps. 6, 7 (Preparing Pre-service Teachers to Integrate Technology into Language Classrooms) also reports changes to curriculum with a more prominent feature of technology, specifically ways to prepare student language teachers to teach in digital classrooms, based on a study guided by two specific research questions: (1) what makes an effective language teacher in a digital classroom? and (2) how can teacher education prepare language teachers to effectively use ICT? The data sources include course curriculum, syllabuses and assessment materials; students' reflections on educational policies on Information and Communication Technologies (ICT); students' reflections on a field trip to an innovative, ICT-saturated learning hub; students' analysis and commentaries on selected research literature on ICT integration in schools and their reflections on the use of the Net Generation Learners Terrace, a new physical learning environment designed to support tele-collaboration. The authors suggested the key principles to develop student language teachers to make pedagogical decisions for the effective integration of ICT in the classrooms.

Chapter 8 (Computational Framework for Modelling Student Engagement in a University's Team-Based Learning Ecosystem) also focuses on technology and education, using a blended approach. It presents a learning analytics framework aimed at discovering salient factors that influence learning outcomes in a Self-directed Team-based Learning (SDL-TBL) environment. This study used online logs and formative assessment scores from Year 1 and Year 2 curricula across two cohorts of students at a medical school. Firstly, it examined the frequency of online access to learning materials and Individual Readiness Assessment (iRA) scores, independently, to compare the distribution of engagement features and iRA scores of two cohorts of students. Second, predictive analytics was developed using the engagement features to predict the learner's iRA scores. Next, regression analysis was performed to gain insights into factors of learner's engagement that could influence their performance. The analyses showed that short-term learning outcomes are predicted by engagement with media-based materials, whereas long-term learning outcomes are predicted by downloads. Also, cumulative and consistent engagement are better predictors than promptness in engagement.

Chapter 9 (Learning Analytics in Online Knowledge Building Discourse) similarly explores blended learning that integrates face-to-face learning with collaborative discussion through an online forum. It investigated the use of learning analytics and its effects in an online knowledge building discourse, contributed by a group of educational professionals. Scaffolds in the form of thinking cues were provided to the learners through the online platform. The analytics include the analysis of usage patterns of scaffolds and the identification of promising ideas in the discourse, which could help students in understanding the key challenges and efforts to sustain idea improvement in a knowledge building discourse. The Idea Identification and Analysis (I^2A) methodology was developed to identify promising ideas in discourse using temporal discourse analysis. It was found the usage of learning analytics with discourse analysis in the practice of knowledge building was beneficial to the students.

Chapter 10 (Features Identification and Classification of Discussion Threads in Coursera MOOC Forums) moves into the online space of learning. In this chapter, the discussion threads of six MOOCs courses offered via the Coursera forums were analysed. The aim was to identify important features that may have an impact on supervised classification analysis in predicting discussion threads that require instructors' intervention. The important features related to thread structures, social network and popularity are identified using Univariate Feature Selection. Classification analyses using neural networks, decision trees and naïve Bayes algorithms were applied to generate predictive models. Assessed based on the level of accuracy, precision, recall and f-measure, the results show that the decision trees algorithm outperformed other algorithms.

Chapters 11 and 12 investigate how learners perceive the learning environment. Based on Bigg's 3Ps (Presage, Process and Product) model. Chapter 11 (Exploring the Relationships of Factor Measures in Blended Learning Environments) reports a study on the relationships of factors in the context of blended instructions that integrated online components with face-to-face instructions. The presage factors include student preferences, course design, instructor presence, student presence and cognitive presence; the process factor measures student approaches to learning; the product factors include student outcomes and course grade. Structural equation modelling pertinent to learner preferences (i.e. active versus passive); course design; instructor, student and cognitive presence and student outcomes showed a marginal fit to the data, indicating that the presage–process–product format could likely act in concert. Contextual differences and the instructor's presence may also influence student approaches to studying.

Chapter 12 (The Evaluation of Informal Learning Spaces in a University) reports an investigation on how learners perceive and "activate" the use of informal learning spaces on the campus. This study took place in the context of a university (Nanyang Technological University, Singapore) that has transformed formal learning spaces (existing tutorial rooms). Two Learning Hubs were built, each housed around 56 rooms that were converted from front-facing tutorial rooms to technology-enriched collaborative learning spaces. One intentional design of the learning hubs is to blur the boundaries between the formal learning spaces (collaborative rooms) and the informal learning spaces (study spaces outside) with glass walls and doors. The authors also studied the informal learning spaces beyond these learning hubs, including benches along corridors. Three key factors that influenced students' choice and use of informal learning spaces were found: comfort, convenience and community (e.g. group discussion). The authors also found that the intentionally built learning spaces in the learning hub were strongly favoured for both comfort and convenience during the time of the semester when classes are held. Less intentional built areas (e.g. along the corridor) were used by students based on convenience but were rated low on comfort.

Finally, Chap. 13 (Conclusions) concludes by explaining how the research work in this book is positioned within the current trends and developments in the society, focusing on higher education, and how the foci of future research are aligned to the emerging trends on neuro-education, machine learning and learning analytics.

1.4 Concluding Remarks

The research reports included in this book are selected projects that CRADLE has worked on, as part of our efforts in taking a research-informed approach towards improving teaching and learning in an institute of higher education. The approach that we shared in this chapter is also a model in the making, constantly evolving in our journey of moving towards enhancing students' learning. Although the studies reported are anchored in Singapore, this book aims to illustrate the transformation efforts in an institution that adopts an integrative approach—an approach that involves researchers from multiple disciplines, traverses the theory–practice nexus, explores a range of work from basic research to applied research, leverages advancement from learning sciences and pushes the boundary of state-of-the-art neuro-education and learning analytics. We are also mindful not to design the studies as an evaluation of specific programmes within a specific context; instead, each study is underpinned by theoretical constructs that are being explored by researchers in the international communities. In this way, the findings can be used as an additional piece of evidence to strengthen the theories and to identify areas for further exploration. We acknowledge that contextual situations and cultural factors need to be taken into considerations when interpreting and generalizing the findings in these studies, as in all other research studies. We hope these studies could contribute to the broader international effort in innovating and advancing the quality of higher education.

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Chapter 2
A Systematic Review of Scholarship of Teaching and Learning Research in Higher Education Institutes from 2014–2019

Zhan Jie How

Abstract This chapter provides a systematic review of the Scholarship of Teaching and Learning (SoTL) research in the higher education context. This review aims to report on the key themes and concerns addressed by SoTL researchers in the last five years. A total of 181 articles were analyzed and five salient themes of research emerged based on how the research questions and/or methodological approaches related to SoTL in the context of Higher Education Institutes (HEIs). These themes are (1) Conceptualizing and framing SoTL, which focuses on the definitions and conceptualizations of SoTL in specific contexts, and the development of conceptual or theoretical frameworks for SoTL; (2) SoTL methodologies and approaches, which concerns particular methodologies used in SoTL research, as well as the synthesis of diverse SoTL methodologies; (3) Teaching and learning strategies and tools, which covers strategies for faculty professional development, strategies for improving student learning experience, and tools for teaching and learning; (4) Applied SoTL research, which includes applied research in the context of specific academic disciplines and across multiple disciplines, as well as SoTL research involving collaborative partnerships between researchers; and (5) Institutional support for SoTL, which comprises strategies and practices for supporting SoTL at the institutional level, the role of education leadership in advancing SoTL, and the development of an institutional culture for SoTL. We concluded the analysis by summarizing the major trends from the literature review and determined specific gaps in the literature to offer suggestions for future research.

Keywords Scholarship of teaching and learning · Conceptual research · Research methodology · Teaching and learning strategies · Applied research · Institutional support

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2.1 Introduction

In view of the proliferation of Scholarship of Teaching and Learning (SoTL) research in recent years, the objective of this chapter is to present a systematic review of the current literature with regard to SoTL in the context of higher education.

The origin of SoTL can be traced back to Ernest Boyer's (1990) seminal work *Scholarship Reconsidered*, where he first coined the term "Scholarship of Teaching" as one of the four different types of scholarship that encompass academic work in institutes of higher learning. The Society of Teaching and Learning in Higher Education (STLHE, n.d.) website defines SoTL as "an emerging movement of scholarly thought and action that draws on the reciprocal relationship between teaching and learning at the post-secondary level." While conceptualizations of SoTL have attracted intensive debate over the years, there is a general consensus in the higher education fraternity that the overarching goal of SoTL is to improve students' learning and enhance educational quality by developing and experimenting with best pedagogical practices (Poole & Simmons, 2013; McKinney, 2006). SoTL has been described as the fastest growing academic development movement in higher education today (Gibbs, 2013), with many academic institutions and national organizations around the world supporting and funding SoTL work since the early 2000s (Simmons & Poole, 2016).

This review seeks to identify the key themes and concerns addressed by SoTL researchers in the past five years, to discuss the main trends and gaps in the literature reviewed, and to provide suggestions on future pathways for SoTL research moving forward.

2.2 Method

A systematic review is an attempt to assemble all empirical evidence that fits prespecified eligibility criteria to answer specific research questions by employing explicit and aprioristically developed methods that are selected with a view to minimizing bias (Green et al., 2015). This chapter follows the steps proposed by Gough, Oliver, and Thomas (2012) in conducting the systematic review, namely (1) Formulation of research question; (2) Searching and screening of studies according to a set of eligibility criteria; (3) Appraisal and categorization of selected studies; (4) Discussion and presentation of identified themes.

2.2.1 Research Questions

This systematic review was conducted with the aim of finding answers to the following research questions:

1. What are some strategies employed by researchers in conceptualizing SoTL and what are some conceptual frameworks developed for SoTL?
2. What are the methodological approaches used in current SoTL research?
3. What kinds of teaching and learning strategies and tools are explored in SoTL research?
4. What are the different types of applied SoTL research?
5. What forms of institutional support are available for SoTL research in Higher Education Institutes (HEIs)?

2.2.2 Eligibility Criteria

To ensure that the articles selected are relevant to the scope of the research questions, the following inclusion criteria were applied in this study: articles included have to

1. focus specifically on the practice of SoTL or teaching and learning research in HEIs;
2. specify the relationship of the study to SoTL in their research question(s) and/or methodology;
3. explicitly state how SoTL influenced or was influenced by actual teaching and learning processes.

The following exclusion criteria were also used to keep the literature database focused on the topic. Excluded are articles that focus specifically on:

1. SoTL in the K–12 context;
2. the advocacy and promotion of SoTL instead of the actual practice of SoTL;
3. educators' or students' attitudes and perceptions toward teaching and learning activities;
4. research ethics within SoTL;
5. the dissemination of SoTL through journals or other platforms.

2.2.3 Searching and Screening Process

After taking into account the several labels used for domains equivalent to or closely related to "scholarship of teaching and learning" and "higher education," we decided to combine all relevant search terms in the search algorithm. Synonyms and alternative expressions widely used in the literature were identified for each search term, resulting in the inclusion of the following search terms:

- Scholarship of teaching and learning: teaching and learning research, teaching and learning scholarship, research on teaching and learning.
- Higher education: college, university, postsecondary.

The search was conducted by using the *OR* operator between synonyms to broaden the search as it pertains to key search terms, in conjunction with using the *AND* operator between different search terms to limit the scope of the search within the extant literature. We further limited the search to articles that explicitly relate to “scholarship of teaching and learning” in the abstract to ensure relevance and applicability of the retrieved literature. The database search was also restricted to the years 2014–2019 to ensure the currency of research in the view of adequately capturing emerging themes in the rapidly changing landscape of SoTL. Only peer-reviewed published journal articles in the English language were included in this systematic review.

A preliminary search of internationally accepted databases such as Academic Search Complete, British Education Index, CINAHL, Communication & Mass Media Complete, ERIC, Education Source, ERIC, Education Source, LISTA, MEDLINE, OpenDissertations, PsycINFO, and Teacher Reference Centre was conducted as of March 12, 2019, which yielded a total of 627 articles. We screened these articles by scanning the titles and abstracts to identify appropriate studies based on the aforementioned inclusion and exclusion criteria, and to remove any duplicates. In total, 181 articles were selected for further review and analysis.

2.3 Findings

2.3.1 Overview of Findings: Major Themes in the Scholarship of Teaching and Learning (SoTL)

The 181 selected articles were reviewed and categorized into five salient themes based on how the research questions and/or methodological approaches are related to SoTL in the context of HEIs: (A) Conceptualizing and framing SoTL; (B) SoTL methodologies and approaches; (C) Teaching and learning strategies and tools; (D) Applied SoTL research; and (E) Institutional support for SoTL. Of the reviewed articles, nearly half of them focused on teaching and learning strategies ($n = 87$), with the next dominant category consisting of articles related to applied SoTL research ($n = 42$), while articles on conceptualizing and framing SoTL ($n = 19$), SoTL methodologies and approaches ($n = 16$), and institutional support for SoTL ($n = 17$) were more or less evenly distributed (see Fig. 2.1). The list of articles corresponding to each category can be found in the Appendix.

In the following sub-sections, we discuss each theme in greater detail to highlight the key issues and concerns that SoTL researchers are addressing.

2.3.2 Theme A: Conceptualizing and Framing SoTL

A common concern among researchers is that the field of SoTL is so broad that what constitutes SoTL is ambiguous and difficult to determine (Mathany, Clow, &

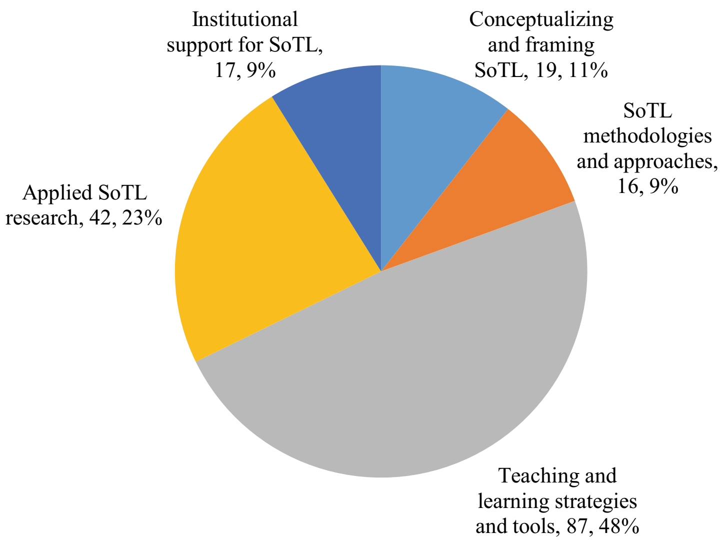

Fig. 2.1 Distribution of articles by theme ($N = 181$). *Note* Data labels include article category, number of included articles, and percentage of included articles

Table 2.1 Sub-categorization of Theme A articles

Sub-category	Description	No. of articles (Total 19)
Definitions and conceptualizations of SoTL	Articles that discuss the definitions and conceptualizations of SoTL in specific contexts	12
Conceptual frameworks for SoTL	Articles that discuss the development of conceptual or theoretical frameworks for SoTL	7

Aspenlieder, 2017), which makes SoTL a widely misunderstood term in academe (Kenny & Evers, 2011). In view of this, over the past five years, a significant segment of SoTL literature has been devoted to discussing SoTL primarily from a theoretical standpoint, which includes defining and conceptualizing SoTL, as well as developing conceptual frameworks or models for SoTL (see Table 2.1).

2.3.2.1 Definitions and Conceptualizations of SoTL

The first sub-category of Theme A articles discusses the definitions and conceptualizations of SoTL in specific contexts. Mirhosseini, Mehrdad, Bigdeli, Peyravi, and Khoddam (2018) conducted an in-depth conceptual analysis on SoTL, and concluded that SoTL can be defined as a sum of defining attributes of research, which includes continuous deep reflection, committed engagement in action, shared publicly, critique-based, critical inquiry process, dynamic process, learning focused, disciplinary, and context-oriented. Leibowitz and Bozalek (2018) introduced the concept of "Slow scholarship" as part of their reconceptualization of the original SoTL concept, so as to realize its potential as a means to enhance teaching and learning in the South African context. Kenny et al. (2017) illustrated the complex interrelationships between educational development, SoTL, and Scholarship of Educational Development (SoED), and developed a seven-principle framework for SoED to help SoED and SoTL researchers inform their scholarly inquiry. Geertsema (2016) discussed the conceptual relationship between academic development, SoTL, and educational research with reference to questions of academic identity and disciplinary expertise. Jaarsma (2015) examined the definitions of the keywords of SoTL—scholarship, teaching, and learning—in order to identify the central hopes and presumptions that underpin SoTL research. Potter and Wuetherick (2015) argued for the need to re-conceptualize SoTL as a truly inclusive and interdisciplinary field to encourage humanist scholars to participate actively in SoTL at the macro (institutional) and mega (national/international) levels. Kern, Mettetal, Dixson, and Morgan (2015) assessed the definitions and taxonomies of SoTL and developed the Dimensions of Activities Related to Teaching (DART) model that organizes teaching-related activities along the public/private dimension and systematic/informal dimension. Simms and George (2014) explored the relationship between assessment and the SoTL, in an effort to identify a systems approach to program management practices. Other articles explored conceptions of SoTL in the specific contexts of music education (Conkling, 2016), the academic profession (Ragoonaden, 2015), social work (Grise-Owens, Owens, & Miller, 2016), and religious studies (Gravett, 2016).

2.3.2.2 Conceptual Frameworks for SoTL

Articles that discuss the development of conceptual or theoretical frameworks for SoTL constitute the second sub-category of Theme A articles. Cruz, Cunningham, Smentkowski, and Steiner (2019) presented a conceptual model for supporting SoTL in the form of a scaffold that delineates the roles and functions played by educational developers in building up the SoTL capacity of their respective HEIs. Booth and Woollacott (2018) developed a conceptual framework which focuses on the internal horizon of SoTL: the didactic, epistemic, interpersonal, moral/ethical, and societal domains; as well as the external horizon of contextual factors that impact the production and implementation of SoTL knowledge: the disciplinary, the professional, the cultural, and the political aspects. Franzese and Felten (2017) proposed adapting a framework from SoTL to serve as a heuristic for the design, implementation, and evaluation of contemplative pedagogies. De Courcy, Loblaw, Paterson, Southam, and Wilson (2017) developed a four-frame model to analyze the nature of SoTL within an institutional context, so as to guide Canadian SoTL leaders in the strategic proliferation and positioning of SoTL. Abdul Rahman, Masuwai, Tajujin, Ong, and Adnan (2016) identified six reliable and valid factors of the Teaching and Learning

Guiding Principles (TLGP)—Intellectual Excitement, Quality Learning, Constructive Alignment, International Cultural, Inquiry Reflection and Good Value, which will be used to develop a framework for teaching and learning in a higher education environment. Walls (2016) examined the potential of using a bioecological model as a guiding theoretical framework for synthesizing SoTL research findings to inform teaching and learning scholarship at the college level. Miller-Young and Yeo (2015) proposed an inclusive conceptual framework for SoTL which delineates the available learning theories in the field and methodologies appropriate to studying teaching and learning across diverse disciplines.

2.3.3 *Theme B: SoTL Methodologies and Approaches*

Articles classified under Theme B focus on various research methodologies and approaches utilized by researchers when conducting SoTL. Sound methodology is generally viewed as the cornerstone of good teaching and learning scholarship, as it enables the researcher to connect the question at the heart of a particular inquiry to student learning (Felten, 2013), and increases the likelihood that the SoTL study is understood and accepted by colleagues (Glassick, Huber, & Maeroff, 1997). To facilitate our discussion of Theme B articles, we divide them into two sub-categories: (a) Discussion of particular SoTL methodologies and (b) Synthesis of diverse SoTL methodologies (see Table 2.2).

2.3.3.1 Discussion of Particular SoTL Methodologies

The first sub-category of Theme B articles examines various individual research methods used by researchers when conducting SoTL. Bonnimann, West, Huijser, and Heath (2018) discussed the potential of exploring pedagogical issues in new ways through the use of learning analytics as it provides SoTL researchers access to data and insights that were previously unavailable. Hardesty, Gluckman, and Hargis (2018) promoted the viability of participation observation ethnography as a primary methodology in SoTL, particularly as a tool for designing research questions. Ng and

Table 2.2 Sub-categorization of Theme B articles

Sub-category	Description	No. of articles (Total 16)
Discussion of particular SoTL methodologies	Articles that discuss and evaluate specific research methodologies employed in SoTL	7
Synthesis of diverse SoTL methodologies	Articles that discuss the grouping and synthesis of multiple research methodologies used in SoTL	9

Carney (2017) examined the possibility of leveraging on scholarly personal narrative as a SoTL methodology, which allows researchers to analyze personal experience as a pool of data through scholarly frameworks. Amundsen, Emmioglu, Hotton, Hum, and Xin (2016) proposed the intentional design of a SoTL initiative, which focuses on the internal coherence and alignment of program design and the thinking underpinning the design. Al Sadi and Basit (2017) investigated the effectiveness of questionnaire-based vignettes as a tool for generating a sophisticated understanding of abstract concepts in teaching and learning research. Svensson (2016) argued for an empirical research approach on teaching and learning which integrated students' understanding of subject matter and faculty presentation of subject matter, and suggested contextual analysis as a relevant methodology to conduct this integrated research on teaching and learning. Pearson, Albon, and Hubball (2015) outlined the benefits of using case study as a key methodology in SoTL inquiry, particularly for its rigor to be credible and generalizable, as well as its flexibility in terms of addressing research questions and employing data collection methods.

2.3.3.2 Synthesis of Diverse SoTL Methodologies

Articles that discuss the grouping and synthesis of multiple research methodologies used in SoTL comprise the second sub-category of Theme B articles. Wilson-Doenges, Troisi, and Bartsch (2016) provided exemplars of published SoTL in psychology based on gold standard benchmarks of methodologies in SoTL that were established in an earlier article (Wilson-Doenges & Gurung, 2013) to show how these benchmarks are achievable for all SoTL researchers. Bloch-Schulman, Conkling, Linkon, Manarin, and Perkins (2016) argued that debates within SoTL about appropriate methodology distract researchers from more significant questions and even lead them to reject SoTL altogether, thus calling on researchers to embrace diversifying methodologies, including the exploratory, representational, and interpretive tools used in the arts and humanities, as well as the observational, experimental, and quantitative approaches adopted in the social sciences. Gurung (2014) argued for even representation of quantitative and qualitative methodological approaches in SoTL, proposing a "fox-like" strategy to SoTL that involves utilizing mixed-methods research designs, and the collection of both quantitative and qualitative evidence. Veilleux and Chapman (2017) developed research methods and statistical knowledge concept inventory that assesses core components of scientific knowledge, statistical literacy, and correct interpretation of study results for further use in SoTL. Rowland and Myatt (2014) designed a heuristic guide to help natural-science faculty with no prior training in SoTL research methodologies to plan, implement, and evaluate SoTL projects. Several articles also focused on the synthesis and unification of current teaching and learning research methods, with the aim of understanding relevant themes associated with these methods that were present in the literature and to identify gaps in the application of such methods (J. Bernstein, 2018b; Divan, Ludwig, Matthews, Motley, & Tomljenovic-Berube, 2017; Chick, 2014; Kilburn, Nind, & Wiles, 2014).

2.3.4 Theme C: Teaching and Learning Strategies and Tools

Theme C articles discuss and evaluate the effectiveness of various teaching and learning strategies and tools used in higher education. While teaching and learning are intertwined processes from a pedagogical standpoint, teaching and learning strategies may differ based on their intended audience. For example, strategies targeted at enhancing the student learning experience are clearly student-oriented, while strategies aimed at faculty professional development are intended specifically for teachers. Another subtle but significant difference is between teaching and learning strategies and tools. While teaching and learning strategies focus mainly on methods and approaches employed by faculty to catalyze learning, the tools are actual instruments or platforms that faculty use to implement these strategies. In view of these distinctions, we reorganize the Theme C articles into three main sub-categories: (a) Strategies for faculty professional development; (b) Strategies for improving student learning experience; and (c) Tools for teaching and learning (see Table 2.3).

2.3.4.1 Strategies for Faculty Professional Development

The first sub-category of Theme C articles focuses on the professional development of faculty, particularly the training and development of faculty in terms of improving teaching quality and developing pedagogical competence.

Articles that concern improving the quality of faculty teaching cover a wide range. They include reviewing manifold teaching strategies from relevant SoTL literature to enhancing the effectiveness of instruction (Richmond et al., 2019; Gan & Geertsema,

Table 2.3 Sub-categorization of Theme C articles

Sub-category	Description	No. of articles (Total 87)
Strategies for faculty professional development	Articles that focus on strategies to improve the quality of faculty teaching	14
	Articles that focus on strategies to enhance the pedagogical competence of faculty	7
Strategies for improving the student learning experience	Articles that focus on strategies to promote student engagement	19
	Articles that focus on strategies to engage students in critical thinking and deep learning	13
	Articles that focus on strategies to improve the effectiveness of student learning	29
Tools for teaching and learning	Articles that focus on learning instruments and platforms to facilitate student learning	5

2018; Ragland, 2016; Sportsman & Thomas, 2015; Mintrom, 2014); engaging faculty in critical reflection and mutual exchange of effective teaching and learning practices through workshops and communities of practice (Hoyert & O'Dell, 2019; Yeo et al., 2019; Rawle et al., 2016; Ossa Parra, Gutiérrez, & Aldana, 2015; Wilkinson, 2014); and engaging faculty in formative reviews to evaluate the quality of their teaching (Blash, Schneller, Hunt, Michaels, & Thorndike, 2018; Crabtree, Scott, & Kuo, 2016; Engin, 2016; Woodman & Parappilly, 2015).

Developing pedagogical competence is another important aspect of faculty professional development. Articles focusing on this aspect discuss various strategies that enable faculty to enhance their pedagogical knowledge and skills. Pelger and Larsson (2018) explored the impact that the writing of teaching portfolios may have on faculty professional learning, a strategy also espoused by Paulson and Campbell (2018). Li and van Lieu (2018) examined the prevalence and the described strategies of faculty members' use of Classroom Assessment Techniques (CATs) to gain a better understanding of how and why they used CATs, which has implications for faculty training of SoTL. Jett (2018) examined the use of children's literature as a pedagogical frame for an undergraduate mathematics content course with preservice teachers to influence their thinking about mathematics teaching and learning. Blais, Motz, & Pychyl (2016) provided a detailed description of the Mentored-Teaching Program (MTP), an initiative in the development of graduate student teaching through discipline-based mentored-teaching practice, which highlights the importance of combining theory with practice in order to develop future faculty into critically reflective educators. Schäfer and Seidel (2015) studied the ability of preservice teachers to use general pedagogical knowledge to notice and reason about specific aspects of teaching and learning processes in classroom situations. Burns (2017) observed the extent to which classroom inquiry supported the pedagogical innovation of faculty as well as their development of knowledge of teaching and learning.

2.3.4.2 Strategies for Improving the Student Learning Experience

Articles that focus on strategies for improving student learning experience can be further divided into three groups: (1) promote student engagement; (2) engage students in critical thinking and deep learning; (3) improve the effectiveness of learning.

Promoting student engagement and ownership in their learning is a significant area of concern for SoTL researchers, leading to the examination of various strategies and approaches such as motivating students to claim ownership of their learning by introducing pre-class reading assignments, in-class group discussions, and the use of exit cards to assess students' understanding (Liang, 2018); promoting student involvement in revising existing curriculum through the use of the Collaborative Improvement Model (Nosek, Scheckel, Waterbury, MacDonald, & Wozney, 2017); and implementing the "jigsaw" method of cooperative learning by organizing classroom activities to enhance inter-dependence among the students so as to enhance their active engagement and participation in the learning process (Yu, 2017). Mengel and

Tantawy (2018) outlined how changes to course design with regard to course requirements and learning activities contributed to increasing levels of student engagement with a social entrepreneurship course, while Thomson et al. (2017) assessed student perceptions of Work Integrated Learning (WIL) and its impact on enhancing student engagement levels. Hunt and colleagues (2016) conducted a systematic analysis of the effect of content delivery media on student engagement, learning outcomes, and instructor behavior. Another important strategy highlighted in SoTL literature is exposing students to purposeful experiential learning to engage them in applied learning experiences (Sheehan, Gujarathi, Jones, & Phillips, 2018; Breunig, 2017; Schaffer, 2017; Ratsoy, 2016; Carlson, Azriel, DeWitt, & Swint, 2014). Researchers also investigated the extent to which faculty–student partnerships in the explorations of new teaching and learning approaches can drive reflective teaching practice and stimulate students' active engagement in their own learning (Bonney, 2018; Donohue-Bergeler, Goulet, & Hanka, 2018; Cook-Sather & Abbot, 2016; Fieldsend-Danks, 2016; Healey, Flint, & Harrington, 2016; Werder et al., 2016; Auten & Twigg, 2015; Allin, 2014).

The second group of articles focuses on strategies used for engaging students in critical thinking and deep learning. Römhild (2019) introduced Rita Felski's (2008) close and reflective reading strategies to literary studies students and assessed the impact of these strategies on students' critical engagements with literary texts. Arellano and Jones (2018) examined the extent to which applying service-learning pedagogy to the curriculum is effective in connecting students to real-world problems and engaging them in deeper learning, a strategy also explored by Reed-Bouley and Kyle (2015) in an attempt to engage undergraduates in theology and religious studies courses. Wang and Selby (2017) proposed reading quizzes in combination with error analysis as a strategy to encourage students to engage in self-reflective learning. Landeen and colleagues (2016) evaluated the impact of curricular renewal on students' learning in undergraduate nursing education. Abdul Razzak (2016) probed the possibility of increasing faculty involvement with students in online contexts as a means for promoting critical thinking and deep learning. Other strategies and approaches include adopting innovative teaching approaches such as online teaching and learning, accessing electronic resources, video conferencing, and research-based teaching and learning to promote creativity and critical thinking in students (Mthiyane & Habedi, 2018); exploring the usefulness of written reflective learning logs in helping students develop critical reasoning ability (Khar, 2017a, 2017b; West, 2014); utilizing active learning and multiple opportunities for practice and feedback to develop discrete skills and habits associated with critical thinking (Heft & Scharff, 2017); developing an integrated, interactive reflective practice syllabus to cultivate students' critical thinking skills (Canniford & Fox-Young, 2015); and encouraging students to read newspapers and articles concerning issues that are relevant to professional training to provoke their critical thinking about highlighted issues (Orlandi & Junges, 2015).

The third group of articles in this sub-category discusses strategies aimed at improving the effectiveness of student learning. Brinthaupt and Ananth (2018) offered recommendations for teaching research methods such as learning the vocabulary and communicating formally in the new language to enhance students' research fluency and proficiency. Lockhart, Wuetherick, and Joorisity (2018) embarked on a multi-stage project that started with understanding the nature of student diversity in the classroom through different lenses, followed by a survey of the impact of high-impact teaching and learning practices, and concluding with a more complex understanding of the foundations for student success. Wood and Cajkler (2018) explored the potential of using a collaborative tool for analyzing and developing an understanding of student known as Lesson Study to harness new and critical insights into teaching and learning. Namaste (2017) evaluated students' transformation of their intercultural competency skills and development by observing their reflective blog entries that they were tasked to write when studying and living abroad. Simonds and Brock (2014) used the scholarship of teaching and learning process as a research model to explore student learning preferences in online courses, concluding that older students had a greater preference for recorded lectures, while younger students were more inclined toward live interactive methods of teaching and learning. Asyafah (2014) considered Tadabbur Qur'an, which refers to the inner reflection of religious texts, as an innovative teaching and learning method to improve the condition of the teaching of Islam across Indonesia. Other articles also reported on teaching and learning strategies and approaches such as exposing students to research at undergraduate level (Guo, Loy, & Banow, 2018; Butcher & Maunder, 2014), developing professional writing skills (Miller, Grise-Owens, Drury, & Rickman, 2018), flipped learning (Jenkins et al., 2017; Sankey & Hunt, 2014), simulated learning (Magana & de Jong, 2018; Englund, 2017), active learning (D. A. Bernstein, 2018a), online learning (McGuire, 2017), peer learning (Glover, Hammond, Smith, & Guerra, 2018; Hanson, Trolian, Paulsen, & Pascarella, 2016; Vaughan & Park, 2016), experimental learning (Campuzano, Matthews, & Adams, 2018; Robinson, 2015; Rahman, 2014), metacognitive approaches (Scharff et al., 2017; Riddell, 2015), use of novel assessment techniques (Adesemowo, Johannes, Goldstone, & Terblanche, 2016; Rouser, 2017), and the use of pedagogically designed guides, rubrics, and taxonomies of learning (Stone, Sara Lowe, & Maxson, 2018; Snow, 2018; Mortier & Yatczak, 2016; Christie et al., 2015).

2.3.4.3 Tools for Teaching and Learning

The final sub-category of Theme C articles focuses on the learning instruments and platforms used by faculty to facilitate student learning. Maxwell et al. (2018) reflected on the practical considerations and lessons learned from implementing Massive Open Online Courses (MOOCs) in college healthcare education. Else and Crookes (2015) examined the official websites of 39 Australian universities on how they presented their teaching and learning profiles online, so as to highlight aspects of teaching and learning that are visible and those which are not. Han (2014) conducted a comprehensive literature review on the use of clicker technology in relation to the 3P (Presage, Process, and Product) model as part of his teaching and learning research on practical delivery methods for enhancing student learning outcomes. Pillay, Bozalek, and Wood (2015) illustrated through the analysis of five qualitative case studies how educators used certain elements of authentic learning in their application of Technology-enhanced Learning (TEL). Hunter, Ortloff, and Winkle-Wagner (2014) reflected on the effectiveness of distance technology as a platform to deliver the teaching of qualitative research.

2.3.5 Theme D: Applied SoTL Research

While SoTL as an academic investigation model is generally concerned with the effectiveness of teaching and student learning, it is also context-specific and derives its legitimacy and substance from its integration into specific disciplines (Stuteville & Click, 2016; McKinney, 2013). As there are varied approaches in how SoTL is applied in different disciplinary contexts at HEIs, we classify the Theme D articles into three separate sub-categories: (a) Applied SoTL research in specific academic disciplines, programs, or processes; (b) Applied SoTL research in multi-disciplinary context; and (c) Collaborative SoTL research (see Table 2.4).

2.3.5.1 Applied SoTL Research in Specific Academic Disciplines, Programs, or Processes

Articles that discuss applied SoTL research in the specialized context of individual disciplines or programs such as Psychology, Sociology, Engineering are guided by the overarching question: To what degree are SoTL findings used in the practice of teaching and learning in a particular discipline?

Table 2.4 Sub-categorization of Theme D articles

Sub-category	Description	No. of articles (Total 42)
Applied SoTL research in specific academic disciplines, programs, or processes	Articles that discuss applied SoTL research and its impact in the context of specific academic disciplines, programs, or processes	32
Applied SoTL research in a multi-disciplinary context	Articles that discuss applied SoTL research and its impact across multiple disciplines	4
Collaborative SoTL research	Articles that discuss applied SoTL research involving collaborative partnerships between researchers	6

In the field of Psychology, Edwards (2017) examined how SoTL-related publications can be used to advance the teaching, learning, and practice of psychology in the university classroom and in applied settings, while Boser, Scherer, Kuchta, Wenzel, and Horz (2017) investigated the combination of evidence-based teaching and SoTL in teaching psychology to inform the implementation of an innovative module for first-year students in an undergraduate psychology program. McKinney (2018) reviewed the literature on the extent to which sociologists made use of SoTL results to instruct the teaching and learning of Sociology and assessed the reasons for the insufficient integration of SoTL in the discipline. McNiff and Hays (2017) proposed exposing Library and Information Sciences (LIS) students to four stages of SoTL training (exposure, encounter, engagement, and extension) to acquaint themselves with the higher education teaching profession. Other academic disciplines associated with applied SoTL research include public administration (Stuteville & Click, 2016); academic librarianship (Otto, 2014; Perini, 2014); business and management (Asarta et al., 2018; Mospan, 2017); counselor education (Minton et al., 2014); political science (Craig, 2014); marketing (von der Heidt, 2018); language learning (Sukandi & Sani, 2017); multimedia, technology, and communication (Yusof et al., 2019); biology (deBraga, Boyd, & Abdulnour, 2015); geography (Hill, Walkington, & King, 2018); gender studies (Hassel & Launius, 2017); geoscience (McNeal & Petcovic, 2017; John & McNeal, 2017); sports engineering (Frank & Donnelly, 2018); healthcare (Anderson & Tunney, 2014; Brackette, 2014; Kelly, 2014); music (Callahan, 2015; Webster, 2014); and religious studies (Zeller, 2018; Gardner, 2016; Clingerman & O'Brien, 2015; Smith, Um, & Beversluis, 2014).

Aside from applied SoTL research in specific academic disciplines, articles in this sub-category also focused on the integration of SoTL into academic programs and processes. Kiessling, Roll, and Henriksson (2017) proposed applying the principles of SoTL as it relates to education management at teaching hospitals to improve both educational quality and working conditions of health care. Openo and colleagues (2017) studied how a research-minded approach provided by SoTL to initiate continuous improvements in QA processes can help faculty better understand and address teaching and learning issues, as well as support student learning in a quality-enhanced environment. Osman and Hornsby (2016) used a SoTL framework as an approach to assimilate ways of thinking about how early-career academics can be supported in their career development at a South African university. Rehrey, Siering, and Hostetter (2014) discussed how three programs collaborated by using SoTL principles to catalyze community building, consensus building, and program assessment at an American HEI, which had a positive influence on the teaching and learning practices of other initiatives not typically considered to be a part of the SoTL agenda.

2.3.5.2 Applied SoTL Research in a Multi-disciplinary Context

The second sub-category of Theme D articles discusses applied SoTL research and its impact across multiple disciplines. McKinney, Atkinson, and Flockhart (2017) focused on three areas in sociology (the face of SoTL in sociology, the sociological imagination, and qualitative methods) that offer potential contributions to psychologists engaged in SoTL, and proposed sociologically based research ideas that psychologists might consider in conducting their teaching and learning research. Hake (2015) analyzed fourteen lessons derived from a Physics education reform effort that may be of value to the teaching and learning of Psychology, concluding that it is conceivable that psychologists can learn something from SoTL in Physics. As conference organizers of the 2012 International Conference on Virginia Woolf, Martin, Holland, and Witiw (2015) engaged with SoTL from a scholarly teaching perspective and investigated cross-disciplinary teaching and learning situations designed for the conference. Cassard and Sloboda (2014) outlined how cross-disciplinary efforts to promote SoTL not only enhance the teaching and learning process but also provide a greater push for HEIs to show accountability in terms of presenting evidence of learning outcomes.

2.3.5.3 Collaborative SoTL Research

In the case of collaborative SoTL research, Wyatt, Henry, and Wilkins (2018) examined a collaborative SoTL study between a Family Medicine physician and educational researcher, concluding that the collaborative endeavor was beneficial for both parties and that such a collaboration has the potential for promoting SoTL work in the domain of medical education. Bozalek, Dison, Alperstein, and Mitchell (2017) investigated the value of academics working together in a collaborative Community of Enquiry (CoE)—Communities of Practice (CoPs) that focus specifically on inquiry—to advance SoTL in higher education. Arrington and Cohen (2015) studied the commonalities, differences, successes, and challenges of conducting collaborative SoTL research between two disciplines—education and sociology—at the micro-level, concluding that micro-level collaboration across disciplines enriches the research experience and contributes to participants' increased engagement with SoTL. Smith and colleagues (2014) illustrated an exploratory approach to the process of forming and maintaining international SoTL collaborative partnerships through virtual pairings. Several articles also discussed the aims, processes, experiences, and outcomes associated with the International Collaborative Writing Groups (ICWG) initiative, which creates a space for collaboration among scholars of teaching and learning who co-author manuscripts on topics of shared interest (Healey, 2017; Healey & Matthews, 2017; Marquis, Healey, & Vine, 2016).

2.3.6 Theme E: Institutional Support for SoTL

There is a prevalent shift in culture in higher education as HEIs increasingly acknowledge the importance of teaching and learning and support for faculty members who engage in SoTL (Schwartz & Haynie, 2013). Institutional support for SoTL is required not only to put in place reward systems that recognize SoTL at departmental and institutional levels, but also to inculcate an appreciation among faculty of

Table 2.5 Sub-categorization of Theme E articles

Sub-category	Description	No. of articles (Total 17)
Supporting SoTL at the institutional level	Articles that discuss various strategies and practices for supporting SoTL at the institutional level	11
Role of education leadership in advancing SoTL	Articles that discuss the ways in which SoTL leaders can promote the growth of SoTL at the institutional level	2
Cultivating an institutional culture for SoTL	Articles that discuss the need and means to develop an institutional culture favorable for conducting SoTL	4

SoTL as a valuable and serious area of research worth engaging (Gurung, Ansburg, Alexander, Lawrence, & Johnson, 2008). Articles categorized under Theme E focus on the various forms of institutional support for SoTL in HEIs, as well as the roles of education leadership and institutional culture in advancing SoTL (see Table 2.5).

2.3.6.1 Supporting SoTL at the Institutional Level

The first sub-category of Theme E articles focuses on various strategies and practices for supporting SoTL at the institutional level. Vithal (2018) discussed conceptualizing and implementing SoTL through an organic approach, which allows SoTL to be gradually institutionalized by encouraging academics to reflect on their practices and undertake scholarly inquiries. Using data presenting SoTL interests and supports at a research-intensive university, Kolomitro, Laverty, and Stockley (2018) identified different types of triggers that prompt individuals to initiate SoTL studies and provided recommendations to build capacity for SoTL at the institutional level. Malfroy and Willis (2018) considered the role of institutional learning and teaching grants in developing the academic capacity to engage effectively in SoTL. Vander Kloet et al. (2017) examined three key conditions of contingency (institutional knowledge, status, and role; invisibility and isolation; and precarity) that may limit or prevent contingent instructors from engaging in SoTL, and called for institutions to change these conditions to support the full engagement of contingent instructors in SoTL work. Trepanier (2017) presented a case for institutionalizing SoTL as a subfield of a political science graduate program so as to bridge the gap between scholarship and teaching within the discipline. Wuetherick, Yu, and Greer (2016) studied the barriers and challenges faced by SoTL practitioners and drew on extant literature to identify best practices for supporting SoTL at the institutional level. Clark et al. (2015) examined how institutional support for SoTL can be used as a mechanism to promote both staff and student engagement with transition pedagogy through the case study of a teaching and learning network. On a more conceptual level, Myatt, Gannaway, Chia, Fraser, and MacDonald (2018) designed a framework to guide conversations for supporting institutional decision-making related to SoTL capacity building, while Simmons (2016) highlighted the importance of social networks, leadership roles, and the notion of a developmental perspective in supporting and sustaining SoTL growth using a micro–meso–macro framework. Other articles also assessed the benefits and limitations of developing organized and institutionally recognized teaching and learning scholarship institutes at HEIs (Marquis & Ahmad, 2016; Marquis, 2015).

2.3.6.2 Role of Education Leadership in Advancing SoTL

Articles that discuss the ways in which SoTL leaders can promote the growth of SoTL at the institutional level constitute the second sub-category of Theme E articles. Miller-Young et al. (2017) proposed a framework that categorizes institutional contexts in terms of micro-level SoTL cultures and macro-level administrative support for SoTL, and used the framework to describe ways in which SoTL researchers can engage in leadership activities to effect change depending on their own context. Verwoord and Poole (2016) applied the concepts of emergent and appointed leadership at different institutional levels to theorize ways in which SoTL leaders can support small significant SoTL networks and facilitate the weaving of SoTL into institutional cultures.

2.3.6.3 Cultivating an Institutional Culture for SoTL

Another important facet of institutional support for SoTL is the development of an institution-wide culture that is conducive to conducting SoTL. West and Stephenson (2016) outlined the first three years of the South Australian/Northern Territory Promoting Excellence Network's (SANTPEN) journey, from defining and operationalizing the concept of SoTL to applying the concept to create a culture of SoTL within and between institutions. Boose and Hutchings (2016) championed SoTL as a powerful counterforce to the erosion of academic culture, by changing the way people think about themselves, their membership in a professional community, their practices as teachers, and their own conception of learning. Using the University of Guelph as a case study, Kenny, Watson, and Desmarais (2016) explored how SoTL has been integrated into the institution's teaching and learning culture based on three catalysts: (1) leadership commitment, (2) reward recognition, (3) integrated networks. Johnson and Ryba (2015) described a systematic approach adopted by an HEI to cultivate a culture for SoTL, starting with needs analysis to document faculty experience with teaching and knowledge of SoTL, followed by the development of an ecological model to classify SoTL projects at the individual, community, and institutional level, culminating in the setting up of teaching improvement projects and certification for faculty interested in SoTL-related studies.

2.4 Discussion

2.4.1 Summary of Key Trends in SoTL Literature

Having reported on the current status of SoTL research, we analyze some significant trends from this literature review. First, the majority of articles focus on tangible teaching and learning strategies and tools or the application of SoTL in specific disciplines, programs, and processes. This suggests that applied SoTL research, rather than conceptual or theoretical SoTL research, represents a prevalent trend in SoTL.

Second, with the emerging conceptions of and evolving methods of conducting SoTL, it comes as no surprise that conceptualizing and framing SoTL constitutes one of the key pillars of SoTL research. What is noteworthy, though, is the fact that researchers are gradually moving away from formulating all-encompassing and broad definitions for SoTL; instead, gravitating toward seeking to conceptualize or re-conceptualize SoTL in relation to specific contexts of study. This context-oriented approach has also been adopted by SoTL researchers in their development of conceptual frameworks or models for SoTL.

Third, within the literature that focuses on SoTL methodologies and approaches, articles are evenly distributed between those that discuss particular SoTL methodologies and those that synthesize diverse SoTL methodologies. This indicates that present SoTL research is not dominated by any singular methodological approach; it is an inclusive field that embraces different methodologies and research methods.

Fourth, while it is fairly predictable that the development and implementation of teaching and learning strategies for enhancing student learning experience is a key area of concern for SoTL research, it is striking to note that researchers are not solely interested in improving the learning effectiveness of students, but also in expounding the concept of “deep learning,” which involves critical analysis, the linking of ideas and concepts, creative problem solving, and application of learning (Harvey & Kamvounias, 2008). This portends a positive transition from focusing solely on the outcomes of instruction to quality of learning, which has significant implications on students’ self-directed learning and academic self-efficacy.

Fifth, the professional development of faculty is a major focus in SoTL research, with a considerable volume of articles devoted to improving the quality of teaching and developing the pedagogical competence of faculty members. This reinforces the notion that both teaching and learning are intertwined processes from a pedagogical standpoint, and any meaningful discussion in the SoTL on enhancing the student learning experience cannot be detached from the continuous development and improvement of teaching strategies and approaches.

Sixth, it is noteworthy that all the five reviewed articles focusing on tools for teaching and learning mainly discussed technology-based tools. This suggests that the SoTL fraternity is aware of the increasingly prominent role played by technology in supporting and enabling learning in higher education, and is keen to examine and evaluate the applicability and effectiveness of these advanced instruments and platforms.

Seventh, our analysis of articles concerning applied SoTL research in specific academic disciplines has shown that the coverage of SoTL is relatively extensive, extending beyond popular disciplines such as Psychology and Sociology to more remote fields of study such as Geoscience and Religious studies. Moreover, there is an upward emphasis on conducting applied SoTL research in the multi-disciplinary context, as researchers observe common teaching and learning research approaches shared by multiple disciplines, and explore the generalizability and transferability of SoTL findings across these disciplines.

Last but not least, institutionalizing SoTL in HEIs is a central theme in recent SoTL research, with several articles examining the strategies and practices for supporting SoTL, as well as the facilitating and inhibiting conditions that may impact the practice of SoTL at the institutional level. This suggests a shift in focus from purely discussing the implementation of SoTL in particular faculties or disciplines to growing SoTL institutionally as well as developing SoTL capability across institutions.

2.4.2 Addressing Gaps in the Literature and Suggestions for Future Research

Following the discussion of the key trends in the current state of SoTL research, it is pertinent to identify gaps in the literature, which could point us to future pathways for SoTL research.

First, there is a need for a greater synthesis between conceptual and applied SoTL research. Conceptual SoTL research aims to define the parameters of the SoTL concept, but most conceptual SoTL studies discuss SoTL primarily from a theoretical standpoint and stop short at expounding how these abstract conceptualizations translate into tangible findings from a practical standpoint. On the other hand, applied SoTL research mainly focuses on seeking concrete evidence (effectiveness of teaching and learning strategies, extent of integration of SoTL into academic programs and processes, successes and challenges of conducting collaborative SoTL research) based on sound methodology; while certain definitions and conceptualizations of SoTL are assumed at the outset to fit the needs of the study, the conceptualization process may not be as rigorous as an academic would normally wish. To address the flaws and inadequacies inherent in each research domain, we suggest that researchers doing both conceptual and applied SoTL research synergize their findings in future collaborative work, so as to achieve greater alignment between these two key strands of SoTL research.

Second, among the 87 articles on teaching and learning strategies, only five focused specifically on technological tools. While there is heightened awareness for the need to integrate educational technology into teaching and learning approaches at HEIs, SoTL research on teaching and learning strategies assisted by educational technology is still relatively lacking as compared to more traditional strategies such as curricular renewal (Landeen et al., 2016), written reflective learning logs (Khar, 2017a), reading newspapers and articles (Orlandi & Junges, 2015), reading quizzes with error analysis (Wang & Selby, 2017), active learning (Helf & Scharff, 2017), peer-led team learning (Glover et al., 2018), metacognitive approaches (Scharff et al., 2017; Riddell, 2015), experimental learning (Campuzano et al., 2018; Robinson, 2015), and the use of pedagogically designed guides, rubrics, and taxonomies of learning (Stone et al., 2018; Snow, 2018; Mortier & Yatczak, 2016; Christie et al., 2015). In contrast, the only teaching and learning strategies directly associated with educational technology are flipped learning (Jenkins et al., 2017; Sankey & Hunt, 2014), modeling and simulation (Magana & de Jong, 2018), access to electronic resources and video conferencing (Mthiyane & Habedi, 2018), and engaging students in online contexts (Abdul Razzak, 2016). This disparity in focus within the theme of teaching and learning strategies is not consistent with the growing influence of educational technology in supporting learning within and outside today's classrooms. Therefore, we suggest that future SoTL research allocates more manpower and resources to investigate teaching and learning strategies assisted by educational technology, as well as to explore the possible integration between these strategies and the more traditional strategies.

Third, following up on the previous point, while SoTL researchers have gradually acknowledged the role of Technology-enhanced Learning (TEL) in supporting and enabling student learning as tools and platforms, there is a need to integrate these tools and platforms with specific teaching and learning strategies or approaches. In our review of the literature, researchers mostly discussed the impact of teaching and learning tools or platforms such as MOOCs (Maxwell et al., 2018), websites (Else & Crookes, 2015), clickers (Han, 2014), and distance technology platforms (Hunter et al., 2014) on student learning in isolation, focusing primarily on the effectiveness of delivery of individual tools or platforms instead of examining the combination of these tools and platforms with authentic teaching and learning principles (Pillay et al., 2015). Moving forward, a potential pathway for SoTL research is to facilitate the interaction and integration between teaching and learning tools and strategies, and to study the possible effects of such integration.

Lastly, despite growing interest within the SoTL community to engage in multidisciplinary and collaborative SoTL research, this form of research is severely underrepresented in the literature as compared to applied SoTL research in specific academic disciplines, programs, or processes. This implies that most applied SoTL studies are still discipline-specific and relatively narrow in terms of scope and focus. To address this limitation, we suggest that researchers with varying academic backgrounds overcome their disciplinary biases and traverse institutional boundaries to engage in meaningful SoTL collaborations at the individual level. At the institutional level, we propose that HEIs set up the necessary support structures to encourage faculty members and researchers to participate in collaborative SoTL projects across different schools and disciplines.

2.4.3 Limitations of Review

As the search of electronic databases was completed in March 2019, literature published since then has not been included in this review. In addition, since our search was restricted to peer-reviewed journal articles, we did not include book reviews, opinion pieces, editorials, or other forms of "grey literature" (research produced by individuals or organizations outside of the traditional or academic publishing and distribution channels) that may be pertinent to the SoTL conversation. Finally, we acknowledge the challenge of assessing the relevance of some articles based primarily on the titles and abstracts, especially when this information could be vague. This could limit the reliability of the selection of articles.

2.5 Conclusions

This systematic review was conducted with the dual purpose of reporting the current status of SoTL research from 2014 to 2019, as well as identifying and addressing key trends and gaps in the literature. In answering the five research questions formulated at the outset of this chapter, we concluded the following points:

1. Researchers mostly adopted a context-oriented approach in defining and conceptualizing SoTL, while conceptual frameworks for SoTL are primarily focused on teaching and learning processes;
2. Aside from discussing and evaluating specific methodologies applied in SoTL research, researchers also explored the possible grouping and synthesis of diversified SoTL methodologies;
3. SoTL research on teaching and learning practices and tools comprises strategies for faculty professional development in terms of teaching quality and pedagogical competence, strategies for improving the student learning experience in terms of promoting student engagement and enhancing learning processes, and the learning instruments and platforms used by faculty to facilitate;
4. Applied SoTL research includes research in the specialized context of individual disciplines, programs, and processes, research in a multi-disciplinary context, as well as collaborative research involving academics and researchers from different fields of study;
5. Institutional support for SoTL research in HEIs is manifested in various strategies and practices for supporting SoTL at the institutional level, the role of education leadership in promoting the growth of SoTL, as well as developing an institutional culture favorable for conducting SoTL.

Moving forward, what can we expect from SoTL research in higher education in the next five years? Our analysis of the current literature has revealed some promising trends that bode well for the immediate future of SoTL research, such as the strong advocacy for deep learning and critical thinking and the increased awareness of the need to integrate technology into teaching and learning processes. On the other hand, we recognize that there are other pathways of research that can be further explored in SoTL, particularly with regard to a stronger link between conceptual and applied SoTL research, the integration between technology-enhanced learning strategies and more traditional strategies, the integration between teaching and learning tools and strategies, as well as greater engagement in multi-disciplinary and collaborative SoTL research.

Appendix

Categorization of reviewed articles by theme

Theme	Description	Reviewed articles (181)
Conceptualizing and framing SoTL	Articles that discuss SoTL primarily from a conceptual standpoint, which includes defining and conceptualizing SoTL, as well as developing conceptual frameworks or models for SoTL	Simms and George (2014), Jaarsma (2015), Kern et al. (2015), Miller-Young and Yeo (2015), Potter and Wuetherick (2015), Ragoonaden (2015), Abdul Rahman et al. (2016), Conkling (2016), Geertsema (2016), Gravett (2016), Grise-Owens et al. (2016), Walls (2016), Booth and Woollacott (2017), De Courcy et al. (2017), Franzese and Felten (2017), Kenny et al. (2017), Leibowitz and Bozalek (2018), Mirhosseini et al. (2018), Cruz et al. (2019) (19)
SoTL methodologies and approaches	Articles that discuss research methodologies and approaches utilized by researchers when conducting SoTL	Chick (2014), Gurung (2014), Kilburn et al. (2014), Rowland and Myatt (2014), Pearson et al. (2015), Al Sadi and Basit (2017), Amundson et al. (2016), Bloch-Schulman et al. (2016), Wilson-Doenges et al. (2016), Divan et al. (2017), Ng and Carney (2017), Svensson (2016), Veilleux and Chapman (2017), J. Bernstein (2018b), Bronnimann et al. (2018), Hardesty et al. (2018) (16)

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Theme	Description	Reviewed articles (181)
Teaching and learning strategies and tools	Articles that discuss and evaluate the effectiveness of teaching and learning strategies and tools used in higher education	Abdul Razzak (2016), Allin (2014), Asyafah (2014), Butcher and Maunder (2014), Carlson et al. (2014), Han (2014), Hunter et al. (2014), Mintrom (2014), Rahman (2014), Sankey and Hunt (2014), Simonds and Brock (2014), Wilkinson (2014), West (2014), Auten and Twigg (2015), Canniford and Fox-Young (2015), Christie et al. (2015), Else and Crookes (2015), Orlandi and Junges (2015), Ossa Parra et al. (2015), Pillay et al. (2015), Reed-Bouley and Kyle (2015), Riddell (2015), Robinson (2015), Schäfer and Seidel (2015), Sportsman and Thomas (2015), Woodman and Parappilly (2015), Adesemowo et al. (2016), Blais et al. (2016), Cook-Sather and Abbot (2016), Crabtree et al. (2016), Engin (2016), Fieldsend-Danks (2016), Hanson et al. (2016), Healey et al., (2016), Hunt et al. (2016), Landeen et al. (2016), Mortier and Yatczak (2016), Ragland (2016), Ratsoy (2016), Rawle et al. (2016), Vaughan and Park (2016), Werder et al. (2016), Breunig (2017), Burns (2017), Englund (2017), Heft and Scharff (2017), Jenkins et al. (2017), Khar (2017a), (2017b), McGuire (2017), Namaste (2017), Nosek et al. (2017), Rouser (2017), Schaffer (2017), Scharff et al. (2017), Thomson et al. (2017), Wang and Selby (2017), Yu (2017), Arellano and Jones (2018), D. A. Bernstein (2018a), Blash et al. (2018), Bonney (2018), Brinthaupt and Ananth (2018), Campuzano et al. (2018), Donohue-Bergeler et al. (2018), Gan and Geertsema (2018), Glover et al. (2018), Guo et al. (2018), Jett (2018), Li and van Lieu (2018), Liang (2018), Magana and de Jong (2018), Maxwell et al. (2018), Mengel and Tantawy (2018), Miller et al. (2018), Mthiyane and Habedi (2018), Lockhart et al. (2018), Paulson and Campbell (2018), Pelger and Larsson (2018), Sheehan et al. (2018), Snow (2018), Stone et al. (2018), Wood and Cajkler (2018), Hoyert and O'Dell (2019), Richmond et al. (2019), Römhild (2019), Yeo et al. (2019) (87)

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Theme	Description	Reviewed articles (181)
Applied SoTL research	Articles that discuss applied SoTL research and its impact in specific disciplines/programs or in collaborative cross-disciplinary research	Anderson and Tunney (2014), Barrio Minton et al. (2014), Brackette (2014), Cassard and Sloboda (2014), Craig (2014), Kelly (2014), Otto (2014), Perini (2014), Rehrey et al. (2014), Smith et al. (2014), Webster (2014), Arrington and Cohen (2015), Callahan (2015), Clingerman and O'Brien (2015), deBraga et al. (2015), Hake (2015), Martin et al. (2015), Gardner (2016), Marquis et al. (2016), Osman and Hornsby (2016), Stuteville and Click (2016), Boser et al. (2017), Bozalek et al. (2017), Edwards (2017), Hassel 2017, Hassel and Launius (2017), Healey (2017), Healey and Matthews (2017), John and McNeal (2017), Kiessling et al. (2017), McKinney et al. (2017), McNeal and Petcovic (2017), McNiff and Hays (2017), Mospan (2017), Sukandi and Sani (2017), Asarta et al. (2018), Frank and Donnelly (2018), Hill et al. (2018), McKinney (2018), von der Heidt (2018), Wyatt et al. (2018), Zeller (2018), Yusof et al. (2019) (42)
Institutional support for SoTL	Articles that discuss various forms of institutional support for SoTL in HEIs, as well as the roles of education leadership and institutional culture in advancing SoTL	Clark et al. (2015), Johnson and Ryba (2015), Marquis (2015), Boose and Hutchings (2016), Kenny et al., (2016), Marquis and Ahmad (2016), Simmons (2016), Verwoord and Poole (2016), West and Stephenson (2016), Wuetherick et al. (2016), Miller-Young et al. (2017), Trepanier (2017), Vander Kloet et al. (2017), Kolomitro et al. (2018), Malfroy and Willis (2018), Myatt et al. (2018), Vithal (2018) (17)

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Part I
Neuroscience and Education

Chapter 3
The Impact of Bilingualism on Skills Development and Education

Chiao-Yi Wu, Beth Ann O'Brien, Suzy J. Styles, and Shen-Hsing Annabel Chen

Abstract The diverse language profiles of learners have posed a critical challenge for education in many multilingual societies. Here we proposed a systematic research framework to address this issue. Within this framework, we reviewed and summarized the findings from several of our studies that examined the impact of bilingualism on teaching and learning in the context of Singapore from different perspectives using a variety of methods, including surveys, behavioural assessment, neurocognitive tasks, and neuroimaging techniques (e.g., functional magnetic resonance imaging). First, we demonstrated the diversity in bilinguals' language profiles using a series of survey studies. Second, we discussed the possible impact of bilingualism on early education by considering various factors that might be associated with language learning and development. Third, we reviewed the existing neuroimaging evidence to delineate how language and reading were represented in the bilingual brain. Finally, we illustrated an ongoing project that employed a combination of multiple methods to investigate the impact of different script types on the neural reading networks for typical and atypical bilingual readers. Our studies have implications for other bilingual societies. Moreover, this chapter establishes the significance and importance of our thriving efforts in bilingual/multilingual research for the science and policy in education.

Keywords Bilingualism · Language profiles · Language learning · Language development · Script types · Neural reading networks

In many multilingual societies, a tension exists between the use of a socially dominant language (for commerce, education, and government) versus the preservation of ethnic languages that are important to members' cultural identity. Every individual student in schools may have a specific profile of strengths across their different

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languages. This diverse student body presents a challenge to education in multilingual societies. Parenting advice and teaching practices established in monolingual communities (like the US, the UK, and Australia) may be poorly suited to the needs of bilingual learners. Therefore, it is vitally important to conduct scientific investigations into language and literacy development within bilingual or multilingual communities, in order to support the educational needs of current and future generations.

The aforementioned scenario is true of many societies that have adopted multilingual policies. In Singapore, for instance, the education policy mandates the development of bilingual proficiency: English plus an ethnic 'mother tongue' (Ministry of Education, Singapore [MOE], 2010). This language policy stems from the diverse cultural and rich multilingual landscape, which provides distinct advantages for Singapore's progress in an increasingly globalized world. The intergenerational bilingualism within Singapore exists in a number of languages with different writing systems, and each individual has a unique language 'fingerprint' arising out of their history of language exposure and use. Therefore, learning materials developed in other countries might have limited applicability in the Singaporean context, where the variety of spoken English has its own unique features blended from the mother tongues. Nevertheless, the rich diversity makes Singapore an informative case to study language and literacy development with bilingual populations.

Using multiple methods, including surveys, behavioural and neuroimaging approaches, researchers have tackled the questions about the possible impact of bilingualism on learning and education from different perspectives. In this chapter, we take the case of Singapore as an example to demonstrate the application of various approaches to investigating this issue. The first step entails a comprehensive understanding of the learner's language profiles. Based on the findings from a number of survey studies, we will illustrate different approaches to understanding the diversity of detailed language backgrounds of the learners in Singapore (Sect. 3.1). Subsequently, focusing on behavioural tests of language development, we will discuss the bilingual impact on teaching and learning for children in consideration of their component skills, alongside internal and external variables (Sect. 3.2). We will then review the existing neuroimaging evidence with regard to the impact of bilingualism on the neural mechanisms for reading (Sect. 3.3). Finally, we will introduce our ongoing research project which integrates profiling, behavioural assessment, and neuroimaging techniques, aiming to elucidate the influence of different script types on the reading networks for typical and atypical biliterate readers in Singapore (Sect. 3.4). Although many of the studies presented here were conducted in the context of Singapore, these findings have implications for other bilingual or multilingual societies, and these approaches can be applied to study the impact of bilingualism on learning and education in other contexts.

3.1 Language Profile of Bilingual/Multilingual Learners in Singapore

3.1.1 Singapore's Languages at a Glance

Singapore has four official languages: English, Mandarin Chinese, Malay, and Tamil. These are the main languages of education and commerce. The main ethnic groups in Singapore are classified as Chinese, Malay, and Indian. The language spoken by each of these groups tends to follow the ethnic groupings. This pattern can be seen in Fig. 3.1, which shows the main language used in different households, as collected in Singapore's most recent Census (Department of Statistics [DOS], 2011). To create this figure, raw numbers were converted to percentages, and rounded for display as a 'unit chart' showing what language use would look like for 100 typical Singaporeans in 2010.

The language environment in Singapore is changing rapidly over time (Bokhorst-Heng & Caleon, 2009; Bolton & Ng, 2014; Gupta & Yeok, 1995; Kirkpatrick, 2010;

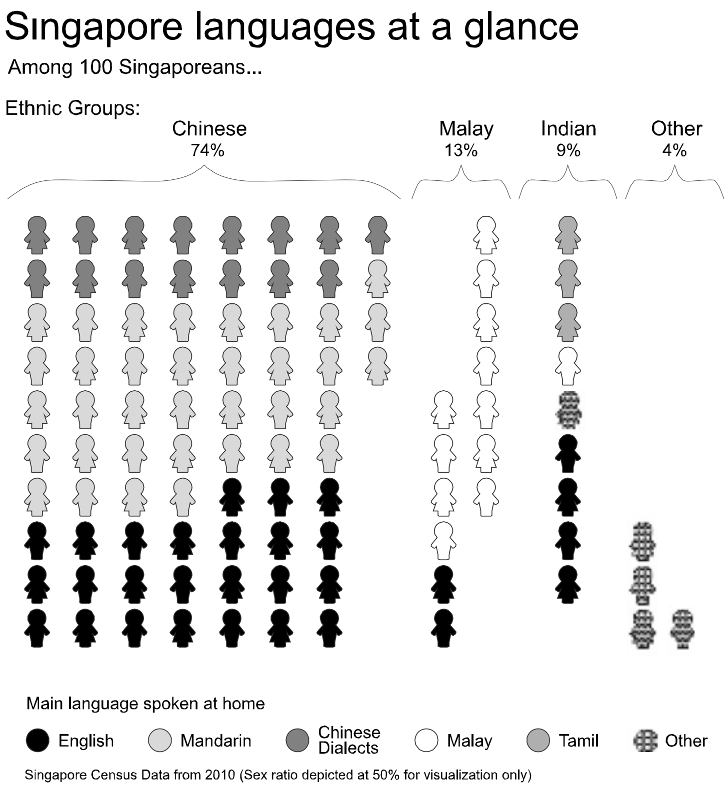

Fig. 3.1 Singapore's languages at a glance. Figure adapted from Styles (2019)

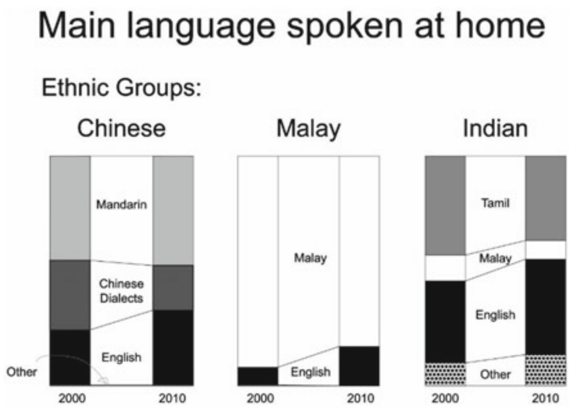

Fig. 3.2 Change in the main language spoken at home 2000–2010. Figure adapted from Styles (2019)

Pakir, 1993), in line with increases in the rates of English language use (Deterding, 2007). Figure 3.2 shows the change in the main language spoken in the home over the 10-year period between Singapore's Census in 2000 and 2010 (DOS, 2001, 2011). In this figure, stacked percentages total 100% of speakers classified within each ethnic group. It is evident in this figure that the use of English as the main language in the home has been increasing at a similar rate for all groups. Among ethnically Chinese Singaporeans, the number of people reporting English or Mandarin as the main language in the home is increasing, while the number of people reporting Chinese dialects is decreasing. Among those classified as ethnically Malays and Indian, the increase in English comes along with decreases in Malay and Tamil.

The increase in English as the main language in the home is largely driven by demographic shifts. English is the main language of education in Singapore, meaning that increasing numbers of younger Singaporeans have high proficiency in English. Figure 3.3 is a population pyramid showing the number of people resident in Singapore for each 5-year age band, starting at age 5–9 years. The left side shows the demographics for the 2000 Census, and the right shows the data from the 2010 Census. The coloured division of each bar represents the proportion of people within that age band, who reported speaking different languages as the main language in the home.

In this figure, the trend for younger Singaporeans to speak less Chinese dialects at home is moving up the age-bands as Singaporeans age. This shift is well recognized (Tan, 2014), and it has been noted that many young adult Singaporeans do not share a language with their grandparents (Gupta & Yeok, 1995). In general, more people in 2010 reported using English as the main language in the home than they did in 2000. The youngest age group in the 2010 Census (5–9 years) is the first to show more than 50% of people resident in Singapore using mostly English at home. These children would now be aged 13–17.

What these figures cannot show is the number of families who use more than one language at home, or how the combinations of languages within a household might differ. It is difficult to get comprehensive statistics on bilingualism at the population

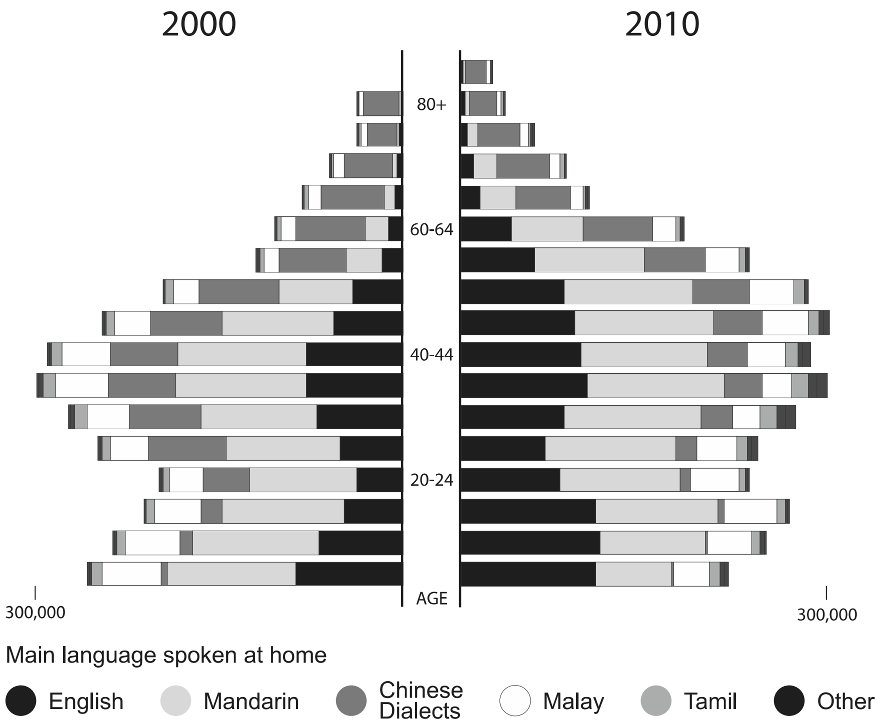

Fig. 3.3 Population pyramid of the main language spoken at home in 2000 and 2010. Figure adapted from Styles (2019)

level, as the official Census does not ask direct questions about the combinations of languages used in the home, or each person's relative proficiency in their different languages.

In order to estimate levels of bilingualism, the nearest proxy measure is a question about which languages each person is literate in. Answers to this question are especially useful for estimating bilingualism in the younger generations where literacy is high (above 99.7% for 15–24 year olds). Figure 3.4 shows the rates at which young people resident in Singapore are reported to be literate in one language, two languages, or three or more languages, broken down by language combination. In this figure, raw data have been converted into the percentage of the population and rounded for display as a unit chart depicting 100 typical young people (aged 15–24) resident in Singapore at the time of the 2010 Census. In this figure, it is clear that at the time of the last census, more than 90% of young people in Singapore reported being literate in more than one language, with the biliteracy rates fairly stable across ethnic groups. Most Chinese young people report being literate in English and Chinese, most Malays in English and Malay, and most Indians in English and Tamil, although other combinations also exist. Almost everyone in this age group was reported to

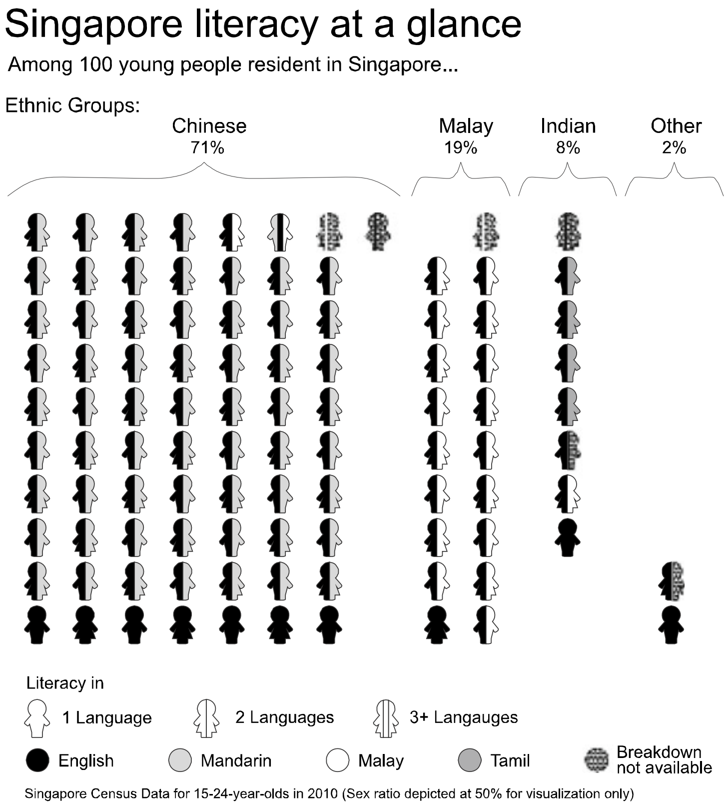

Fig. 3.4 Literacy data from Singapore's 2010 Census. Figure adapted from Styles (2019)

be literate in English, and English-only literacy was evident for around 10% of the population.

In summary, Singapore's Census data shows that the majority of people in Singapore exhibit language usage consistent with the 'mother tongue + English' model of bilingualism at the heart of Singapore's bilingual education policy (MOE, 2010). The census data also shows demographic shifts in the main language used in the home, with increasing numbers using mainly English, which is primarily driven by changes in the younger age bands. This pattern is especially clear in the literacy rates for younger Singaporeans (15–24 years), where biliteracy in English accounts for almost all reported literacy. What these official statistics are not able to reveal is how many languages are used at home in different households, or how different combinations of languages might contribute to effective bilingualism and biliteracy. In order to bridge this gap, a variety of different methods are needed to document detailed language usage in the homes of young Singaporeans, and to investigate how different patterns of language use contribute to the emergence of effective bilingualism and biliteracy, as a child transitions from the home into formal schooling. The following section describes our initial investigations into the relationship between mixes of languages used in the home during early childhood, and later language proficiency.

3.1.2 Spoken Languages in Early Childhood

In a recent study (Bhattacharjee, Woon, & Styles, Manuscript in preparation), 181 Chinese-speaking undergraduates completed an extensive language questionnaire, called the Language Fingerprint. Participants rated their proficiency in four domains of language: Understanding, Speaking, Reading, and Writing, using a scale adapted from the Language Dominance Self-Report Tool (Lim, Rickard Liow, & Lincoln, 2008), and estimated how much different caregivers spoke to them in different languages. According to exploratory factor analysis, a single factor accounted for variance in the composition of the early language mix and self-reported language proficiency as an adult. A schematic representation of this factor is shown in Fig. 3.5. The model revealed that undergraduates who reported more exposure to Mandarin Chinese and/or Chinese dialects in the early years reported they had better language skills in Mandarin Chinese, and acquired their English later than those who heard less Chinese. Conversely, undergraduates who reported more exposure to English reported they acquired their English earlier on, heard less Chinese, and reported worse

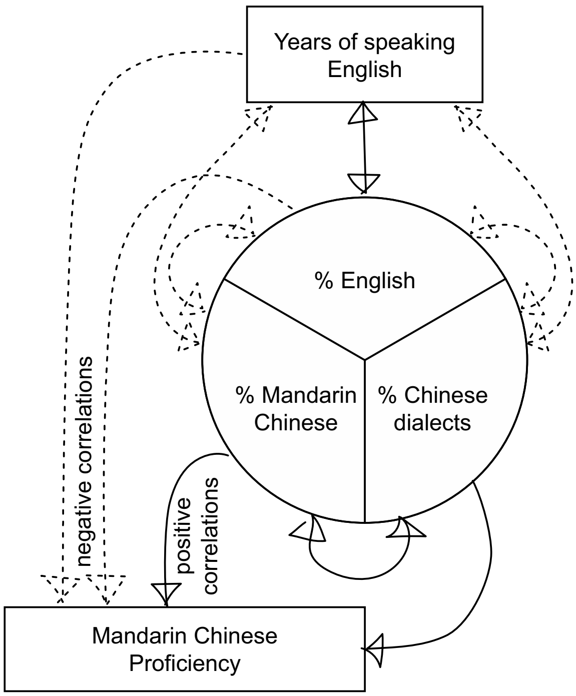

Fig. 3.5 Schematic representation of relationships between early language exposure (0–5 years) and language proficiency, according to self-report of young Singaporean adults

language skills for Mandarin Chinese. Importantly, the relationship here is asymmetrical, as early English negatively impacted self-reported language skills in Chinese, but early exposure to Chinese dialects did not negatively impact self-reported language skills in English. This finding is consistent with evaluations of language proficiency in school-aged children (see Sect. 3.2 for further details), suggesting that the details of the home language environment are important for supporting effective bilingualism in Mother Tongue languages in Singapore.

Since these data are self-reported, it is possible that they do not capture the true language proficiency for Singaporean adults. Furthermore, since the language exposure questions ask students to recall the linguistic interactions they had as children, they may be subject to hindsight bias (e.g., being good at Chinese as an adult makes one report hearing more Chinese as a child). Nevertheless, these results suggest that the fine-grained details of the early language environment are linked to language proficiency later in life, and support the use of detailed evaluations of language context (more complex than ‘which language was used most’), and language skills (more complex than a simple measure of ‘dominance’).

In short, this study shows that different constellations of the language spoken in the home contribute to the kind of effective bilingualism observed in Singaporean adults, and shows a more nuanced way of understanding patterns of bilingualism. The asymmetrical relationship between early exposure to English (reduces Mother Tongue proficiency) versus early exposure to Mother Tongue or dialects (no effect on English proficiency) is consistent with the idea that English is well supported in the education system, and that earlier exposure to English did not provide additional English language learning advantages in this group of young adults.

3.1.3 What We Don’t yet Know

In this sample, we focussed only on Chinese/English bilinguals, as they were the most numerous group in the undergraduate cohort. We don’t yet know if the same pattern of asymmetry for English versus Mother Tongue is consistent across the languages of Singapore, nor if it is a pattern that generalizes across disciplines (e.g., undergraduates taking Chinese studies), or more broadly in the population (Singaporeans not pursuing higher education). Given the retrospective self-report nature of the survey, language input in the preschool years is reduced to a single self-reported time bracket (0–5 years), so it is unclear how consistent the language exposure was over this time period, and how different households might have adapted or changed their language use as their children aged. In our future studies, we are conducting more-detailed investigations of the particular language mixes children are exposed to at different time points, so that we can better link language mixes at a given time with multivariate language proficiency outcomes across the different domains of understanding, speaking, reading and writing. In the next section, we present research on these language mixes using direct measures of language proficiency to examine different components of bilingual language processing.

3.2 The Impact of Bilingualism on Teaching and Learning

Like many children around the globe, Singaporean children come to school with great variation in linguistic experiences from the home, society, and media, as indicated in Sect. 3.1. Therefore, research on bilingual development becomes a critical source of information pertinent to their education. Such use-inspired basic research (Stokes, 1997) hails from the perspectives of developmental, cognitive, and neurosciences, along with linguistics. In this section, we consider language learning from two perspectives: first, the component skills for processing and using language (phonological, lexical, syntactic), and second, the variables that are associated with and affect language learning (internal and external variables). We then survey a set of studies on bilingual learning within the context of Singapore.

3.2.1 Component Skills

Cognitive, neuroscientific, and linguistic research suggest that linguistic competence may be conceptualized as (at least) three distinct forms of linguistic knowledge related to the phonological, lexical, and syntactic structure of language. Developmentally, these forms of knowledge may be attained at different rates. Phonological tuning to the speech sounds that are specific to ones' native language(s) occurs early in life, around 12 months (Kuhl, 1993). Lexical knowledge, or the set of known words often referred to as one's vocabulary, also begins early in life with a significant burst in learning new words around 18 months of age, but with acquisition extending at a rate of about 2,000–3,000 words annually during the school years (Nagy & Herman, 1987), and continuing throughout the lifespan. On the other hand, syntactic knowledge, or understanding of grammatical principles underlying word integration which enables one to produce and comprehend an infinite number of sentences, develops a bit later at about 2–3 years with further refinements through the teen years (Brown, 1973).

Besides different rates of acquisition, Ullman (2001) suggested that the nature of these forms of knowledge also differs. Vocabulary and phonology both involve arbitrary mappings between word labels or speech sounds and their meanings or referents, and so they are said to draw on declarative memory as more explicit forms of knowledge. Syntax involves more rule-like aspects of language, and so requires procedural forms of memory, often described as implicit knowledge. Moreover, performance on tasks that are related to these three component processes correlate with activity in different brain structures (e.g., Wong, Yin, & O'Brien, 2016), supporting the linguistic model of encapsulated systems with dedicated interfaces (Jackendoff, 1997).

Francis (2012) extended Jackendoff's model to the Bilingual Tripartite Parallel Architecture, which includes separate modules for each language in terms of knowledge about the phonological structure, syntactic structure, and vocabulary knowledge, although the latter also involves a cross-language interface. For multilingual development, these different language domains show different degrees of dual language integration. In a cross-sectional sample of bilingual Welsh-English children aged 2–3, 7–8, and 13–14, Mueller-Gathercole, Thomas, Roberts, Hughes, and Hughes (2013) showed that first (L1) and second (L2) language performance on vocabulary and grammar tasks deviated for the two languages in the primary school years, but the gaps closed in their oldest group. Specifically, grammar performance was correlated between languages for their 2–3, 7–8, and 13–14 year-old groups, while vocabulary performance was only cross-linguistically correlated within their oldest group. This suggested that learning a new grammar was relatively 'easier' than a new set of vocabulary, probably because vocabulary involves learning many word types with few tokens, while grammar involves few types of structures with many tokens per type (Tham et al., 2005). This indicates that bilingual proficiency may vary depending on the competencies being examined.

Further, patterns of brain activation correlated with L2 phonology and syntax knowledge are more sensitive to age of acquisition (AoA) effects (less activation with earlier AoA), while neural correlates for L2 lexical semantics are more sensitive to proficiency levels (with more L1-like activation for higher L2 proficiency) (Wong et al., 2016). Thus, while it is generally accepted that cross-language influence exists for multilingual individuals (Cummins, 1991; Koda, 2008), the degree of influence may vary across the component skills, and may depend on factors of language use and history as well as the typological distance between languages (Branum-Martin, Tao, Garnaat, Bunta, & Francis, 2012; Kahn-Horwitz, Schwartz, & Share, 2011; Melby-Lervag & Lervag, 2011).

To meet the educational needs of students, a better understanding of the language competencies and shared interlingual knowledge that contributes to language and literacy proficiency will be informative. In general, language use and proficiency change over time, and bilingual status is, therefore, dynamic (Grosjean, 2013). Family history, over the long term as generational cohorts, and more proximally as the first linguistic environment of the child, plays a significant role in the individual child's dynamic time-course. Whether one's form of bilingualism is simultaneous or sequential depends on early language exposure, primarily through the family environment. Sequential or second-language acquisition also may result in additive bilingualism, where proficiency is maintained in two languages, or subtractive bilingualism, with first-language attrition. These complex developmental patterns are equally plausible in multilingual societies such as Singapore. The result is that many variations of bilingualism co-exist within a single classroom. Furthermore, children may be at different points in different developmental trajectories. Therefore, it is important to consider variables related to their language and literacy development, including both external variables that affect the input to the child, and internal variables that constitute the child's cognitive and motivational status.

3.2.2 Internal and External Variables

The Specificity Principle for Multiple Language Learning laid out six moderating variables for multiple language learning (Bornstein, 2013). These consisted of what would be considered 'internal' processes, as person-related variables like language ability and attitudes towards learning other languages. Along with this is the outcome of one's ability and attitude—the proficiency for language production and comprehension, and knowledge about phonology, semantics, grammar, and pragmatics for language. Other moderating variables would be considered as 'external' to the person—the setting (the linguistic characteristics of social structures in which children reside), time (age of acquisition, duration of exposure, heritage), and mechanisms for learning (direct instruction or modelling of language, and encouragement to use it).

We considered the internal and external variables that contribute to children's bilingual literacy attainment in Singapore and internationally, following Bronfenbrenner's (1979) broad ecological systems framework for children's learning as an interplay between the person and environment (O'Brien et al., 2014). External factors of the community, school and home environment were concluded to play a key role in acquiring and maintaining literacy in a heritage or ethnic language that is not the main societal language. Internal factors were found to contribute to the language of instruction and society, which was English in the case of Singapore.

External variables appear to contribute to children's explicit language use. Parents' bilingual proficiency, language use patterns, language attitudes, and perceptions towards bilingualism are critical factors that contribute to children's pattern of language use (De Houwer, 2007; Portes & Hao, 1998), and generational shifts in language use will also affect the probability of children's multilanguage use (Cavallaro & Serwe, 2010; Vaish, 2007). Length of exposure to second or additional languages also facilitates language transfer between the first and second languages. Mihaljević Djigunović (2010) studying 14-year-old Croatian English-language learners found that those who started learning the L2 earlier showed stronger inter-language relationships in listening, reading, and writing than late starters. Research on grammar representation (Clahsen & Felser, 2006; Clahsen & Hong, 1995) has pointed to fundamental differences in secondary language learning, which is frequently incomplete and shallow. However, research has also shown that the nature of the language learning environment modulates learning outcomes, where exposure to naturalistic environments leads to more native-like proficiency by second-language learners (Pliatsikas & Marinis, 2013).

On the other hand, internal linguistic factors might be more important for cross-linguistic transfer (e.g., Hulk & Müller, 2000), and it is generally the case that first-language properties affect those of the second, or that there is a mutual influence for simultaneous bilinguals (van der Linden & Blok-Boas, 2005). Phonological and morphological awareness, for instance, are strongly related to literacy attainment and can be transferred across languages, whereas metacognitive skills may be trained and can facilitate reading comprehension within and across languages. Verbal working memory may contribute more heavily to reading acquisition and skills when the second language is very different from the first, with regard to how the written language represents oral language. For instance, verbal working-memory span contributes to English–L2 text comprehension by Hebrew-speaking secondary students (Abu-Rabia, Share, & Mansour, 2003), Chinese and other English-as-second-language (ESL) kindergarteners (Low & Siegel, 2005), and Korean-English bilingual children (Pae & Sevcik, 2011). de Abreu, Gathercole, and Martin (2011) demonstrated in a multilingual environment of Luxembourg that whereas the short-term storage component of working memory was linked to vocabulary development, the cognitive control component of executive functions was uniquely related to syntax and early reading development.

Given the variation across individuals in multilingual societies regarding their history of language use, sustained proficiency, and typologies of learned languages, we examined some of these factors through investigations of phonological awareness and reading, vocabulary knowledge, and grammatical knowledge in a set of studies based in Singapore described in the following section.

3.2.3 Phonological, Lexical, and Syntactic Knowledge for Bilingual Learners

In a study of phonological awareness, we examined performance for three bilingual groups in Singaporean kindergartens (O'Brien, Mohamed, Yussof, & Ng, 2019). Children were exposed to and were learning two of the official languages of Singapore: English for all, plus their mother tongue language of Mandarin, Malay, or Tamil. In the study, 612 children were followed over a 2-year period when they were 4–6 years of age, and they were assessed on English measures of syllable, onset-rime, and phoneme level awareness, plus vocabulary and reading. It was predicted that the child's other language would influence their performance in English depending on the typology and oral language structure. In particular, following predictions based on the psycholinguistic grain size theory (Lallier & Carreiras, 2018; Ziegler & Goswami, 2005) Mandarin-English and Malay-English children showed greater syllable-level awareness, following from a more salient syllable structure in these oral languages. Tamil-English children, on the other hand, showed greater phoneme level awareness, following from a more consistent phoneme-to-grapheme mapping of the oral to written language for Tamil.

The patterns of phonological awareness levels also predicted early English reading skills differently amongst these bilingual language groups. Attention to larger grain size facilitated reading for the Mandarin-English and Malay-English bilingual children, but not for the Tamil-English children. For these children, their English vocabulary knowledge moderated the effect of phonological awareness on reading, whereby those with high vocabulary scores showed a stronger relation of phonological awareness to reading, similar to monolingual findings (Dickinson, McCabe, Anastasopoulos, Peisner-Feinberg, & Poe, 2003). Overall, the findings showed that cross-language influences of both oral language (e.g., structural properties) and orthography (e.g., grain size accommodation) can impact early literacy development for bilingual learners.

In another study examining vocabulary development, a set of 805 bilingual kindergarteners from Singapore were evaluated for their receptive vocabulary in two languages: English plus the mother tongue language of Mandarin or Malay or Tamil (Sun, Bin, & O'Brien, 2018). Following up on prior second-language research, it was hypothesized that internal variables (nonverbal reasoning, working memory, and phonological awareness) would more strongly predict English vocabulary knowledge, whereas external factors (language input in the home, age of acquisition, and number of books in the home per language) would have a greater impact on mother tongue vocabulary. This was expected based on the idea that a 'threshold' is required for language input in order for individual differences in internal variables to manifest their effect on language learning (e.g., Paradis, 2007; Unsworth, Hulk, & Marinis, 2011).

Given the setting of Singapore, in which the dominant societal language and medium of instruction are English, this implies English would meet the input threshold, and therefore internal variables would become more important in vocabulary learning, similar to what was found in naturalistic learning settings. The mother tongue languages, on the other hand, have limited exposure and so children's vocabulary learning, in this case, would be subject primarily to external factors, similar to what has been found in instructional settings. The findings supported the hypotheses, that, while both internal and external factors explain lexical knowledge in each language, the relative contribution is greater from internal factors for English, whereas external factors were more important for ethnic language knowledge. The differential outcome follows from the critical mass hypothesis (e.g., Elman, 2003). Note that the results of this study are consistent with the relationship between home language exposure in the early years, and self-reported language proficiency in adulthood (See Sect. 3.1), where Mother Tongue proficiency was influenced by the amount of exposure to Mother Tongue (and related varieties), but proficiency in English was unaffected by the nature of the language mix in the early years.

In a third study, we examined grammatical knowledge of 228 Singaporean Chinese-English bilinguals in primary (grade 5) and secondary (year 2) school (Bin & O'Brien, 2017). In particular, two forms of grammar knowledge were evaluated: telicity, or the sense that an event has reached completion (such as 'I ate the apple' vs. 'I eat apples'), and mass/count distinction, where countable nouns represent discrete objects, but mass nouns represent substances without such boundaries (apples vs. milk). Each property is reflected differently in English compared with Chinese grammar, and so we investigated cross-language influence based on students' performance. Objects in a definite noun phrase ('the apple') suggest telicity in English, but could be interpreted either way in Chinese. For English, only count nouns are pluralized, whereas for Chinese there is no morphologically different form for count and mass nouns (rather, classifiers are used for count nouns). Using grammaticality judgement tasks, all participants showed worse performance on the definite noun phrase parts of the task, and this was especially true for those with more dominant Chinese proficiency. All participants performed better overall on the mass/count task, but mass nouns and plural morphology still presented difficulties. Findings were interpreted to suggest that morphosyntax precedes semantic knowledge for language learning of bilingual youths.

To summarize, across the three studies, we observed cross-language influence and moderating variables on language and literacy learning. For phonological awareness in young preschool children, the typological distance of their mother tongue influenced their level of phonological awareness and its relation to reading. For vocabulary, English and mother tongue language learning differed, with internal variables affecting the former and external variables affecting the latter in preschool children. With regard to grammar knowledge, we also found that two distant languages, English and Chinese, showed cross-language influence in school children's performance especially for understanding telicity in the context of mass and count nouns.

3.2.4 What We Don't yet Know

We focused on samples of bilingual children in a wide age range across the three studies, and found evidence of cross-language influence specific to the sets of their known languages. These snapshots of language performance do not give us a full picture of the developing and mature language systems within bilinguals, however. The use of behavioural measures also does not give insight into the mechanisms underpinning the influences of different languages on emerging proficiency—for example, whether bilinguals are using the same or different cognitive systems for processing their different languages. For a closer look at processing these different sets of languages within developed bilingual systems, we turn in the next section to a set of studies using neuroimaging with young adults.

3.3 Neuroimaging of the Bilingual Brain

We now shift the focus to how language processing and reading are represented in the bilingual brain. It is important to understand the similarities and differences in the underlying cognitive processes and neural mechanisms between the languages that bilinguals use. If there are differences between languages, the existing knowledge about language processing that is primarily based on monolingual speakers cannot be simply generalized to bilingual speakers.

Advanced neuroimaging techniques such as functional magnetic resonance imaging (fMRI) have offered a non-invasive way to investigate the neural correlates underlying language processing and reading. When a brain area is in use, it consumes energy which is carried by oxygenated haemoglobin in the blood. Functional MRI detects the changes in the blood oxygen level which was induced by neural activities adjacent to the blood vessels. The blood-oxygen-level-dependent signals measured by fMRI are, therefore, used to infer neural activities in the brain. FMRI has been commonly used as an investigative tool to examine the neural underpinnings of language processing and reading in bilingual research. The evidence provided by the existing neuroimaging studies has substantially extended our understanding of the cognitive processes of language from behaviours to the brain.

3.3.1 One System or Two?

One of the fundamental questions in bilingual research is whether bilinguals utilize shared or distinct brain networks for processing the languages they use. The existing neuroimaging studies have yielded inconsistent findings. On the one hand, several studies have suggested that bilinguals use a single neural system to process multiple languages. For example, similar cortical responses were found to be engaged in processing auditory stories for high proficient late Italian-English and early Spanish-Catalan bilinguals (Perani et al., 1998). Early proficient Chinese-English bilinguals recruited similar neuroanatomical networks for comprehending visually presented sentences in both languages (Chee, Caplan, et al., 1999). Both early and late proficient Chinese-English bilinguals showed overlapped cortical regions for single word processing (Chee, Tan, & Thiel, 1999). No between-language differences were found for English speakers who acquired French after the age of 5 during phonological and semantic generation in both languages (Klein, Milner, Zatorre, Meyer, & Evans, 1995) and for Chinese speakers who learned English in adolescence during verb generation (Klein, Milner, Zatorre, Zhao, & Nikelski, 1999). These studies have implicated that highly proficient bilinguals, regardless of the age of acquisition of their L2, engage common neural networks for processing their L1 and L2.

On the other hand, between-language differentiation in the neural recruitment has also been shown. Tham et al. (2005) reported distinct brain regions involved in phonological processing in Chinese and English for early bilinguals who were exposed to both languages before the age of 5. Leonard et al. (2010) examined word processing in proficient Spanish-English bilinguals who acquired English at around the age of 6 using Magnetoencephalography (MEG). They found that throughout the course of word processing, L2 recruited a more extended network including the posterior and right-hemispheric regions, suggesting that the brain might recruit supplementary areas for processing words that were less familiar (in L2). Using fMRI and multivariate pattern analysis, Xu, Baldauf, Chang, Desimone, and Tan (2017) demonstrated that late Chinese-English bilinguals utilized common brain regions but distinguishable patterns of neural activities in reading the two languages, implicating that different languages in bilinguals are represented in functionally independent neural computations. Other studies have suggested that second languages acquired during the early stages of language development (i.e., in early, simultaneous bilinguals) tend to be represented in the same brain regions as the native language, whereas second languages acquired later in life (i.e., in late, sequential bilinguals) do not necessarily share the same brain regions as the native language (Kim, Relkin, Lee, & Hirsch, 1997). The findings of different neural representations for processing native and second languages have been replicated in late French-English bilinguals (Berken et al., 2015; Dehaene et al., 1997), late Italian-German bilinguals (Wartenburger et al., 2003), late Russian-English bilinguals (Marian, Spivey, & Hirsch, 2003), and late Spanish-English bilinguals (Pillai et al., 2003). These studies suggest that not only proficiency level but also the age of acquisition of L2 seem to have impacts on whether the native and second languages share common neural representations.

3.3.2 Neural Representations of L1 and L2 Reading

When it comes to reading, other factors such as how written scripts are mapped onto the corresponding pronunciation may also play a crucial role in influencing the neural representations of reading in bilinguals. In particular, orthographic depth—the degree to which the written scripts can be mapped to the pronunciation via one-to-one letter-phoneme correspondence, determines which route individuals adopt to access phonological representations in reading. Reading a transparent writing system (i.e., shallow orthography, such as Spanish) could rely on the sublexical route where the graphemes within the words are converted to phonemes. Reading an opaque writing system (i.e., deep orthography, such as Chinese) would require the lexical route where the corresponding pronunciation of the orthographic input can only be retrieved from memory. The sublexical and lexical routes of reading (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001) have been shown to engage different areas in the brain. The sublexical route has been associated with brain activation in the dorsal stream encompassing the posterior superior temporal gyrus, inferior parietal lobule, and dorso-posterior inferior frontal gyrus, whereas the lexical route has been shown to engage brain areas in the ventral stream including the fusiform gyrus, posterior middle temporal gyrus, and ventro-anterior inferior frontal gyrus (Jobard, Crivello, & Tzourio-Mazoyer, 2003). Hence the dorsal stream is associated with grapho-phonological conversion, and the ventral stream is known to be related to lexico-semantic processing.

For bilinguals, reading a more transparent language engages neural activation in the dorsal stream, while reading a more opaque language recruits the ventral stream. These findings have been reported in a variety of language pairs including the following (where the more transparent language is listed before the more opaque): Spanish-English (Boukrina, Hanson, & Hanson, 2014; Meschyan & Hernandez, 2006), German-French (Buetler et al., 2015), and Hindi-English (Cherodath & Singh, 2015; Das, Padakannaya, Pugh, & Singh, 2011).

Moreover, the differences in scripts may shape cross-linguistic transfer between the languages of bilinguals, which may, in turn, alter the reading strategies and cognitive resources used for reading each language, according to the grain size accommodation hypothesis (Lallier & Carreiras, 2018). For example, bilingual readers who acquire reading in a deep and a shallow orthography would rely more on larger grains (e.g., increased reliance on lexical or whole-word processing) when reading their shallow orthography as compared to monolinguals reading the same shallow orthography. The cross-linguistic transfer due to differences in the orthographic depth between languages of bilinguals has been shown in a number of neuroimaging studies. Yokoyama et al. (2013) found that Chinese (L1) learners of Japanese (L2) and Korean (L1) learners of Japanese (L2) showed differential brain activation during Japanese (L2) reading, when proficiency and the age of acquisition were balanced. This study supported the idea that cross-linguistic differences in L1 and L2 orthographic depth influence the neural representations of L2 reading. In a recent study, Oliver, Carreiras, and Paz-Alonso (2017) demonstrated that the differential recruitment of the dorsal and ventral streams depended on the L2 transparency. Late proficient Spanish-Basque (transparent L2) bilinguals showed functional co-activation between the left ventral occipito-temporal cortex with the areas in the dorsal stream, whereas late proficient Spanish-English (opaque L2) bilinguals had co-activation with the regions in the ventral stream. The above-mentioned studies indicate that the orthographic depth of L1 and L2 shapes the neural representation for reading each language, and moreover it has cross-linguistic transfer effects that may induce changes in the reading strategies and the underlying neural networks that vary from monolingual readers of that language.

To sum up, the neural representations of L1 and L2 for bilinguals may be influenced by a number of factors such as the age of acquisition of L2, proficiency level, and orthographic depth of each language. All of these may have contributed to the inconsistent findings with regard to whether bilinguals utilize shared or distinct neural networks for processing their languages. Furthermore, it remains unclear how these neurological processes develop as a bilingual child learns to read in their different languages.

3.4 The Effective Biliteracy Project

In the previous sections, we have demonstrated the diversity in the language background profiles of learners in Singapore (Sect. 3.1). We have discussed the development of component skills for reading and the impact of internal and external variables on language and literacy attainment for bilingual children (Sect. 3.2). We have also reviewed the existing neuroimaging studies on the neural representations of language processing and reading for bilinguals (Sect. 3.3). The research has provided insight into the complexity of the neurocognitive processes in bilinguals. Meanwhile, it suggests that a systematic research framework is required for investigating the impact of bilingualism on education and learning.

Taking a multimodal approach, we embark on a research project that aims to investigate the impact of different script types on the neural reading networks for typical and atypical biliterate readers. We target two prominent bilingual groups in Singapore, Chinese-English and Tamil-English bilinguals. While the two groups share English as the common language, their mother tongues are quite distinct from each other. Chinese has an extremely opaque script set, whereas Tamil has transparent orthographies. Given that the writing systems and orthographic depth vary among these two languages and English, the project aims to elucidate how different script types may shape the neurocognitive network of reading in bilinguals. In particular, we will examine how the script of the mother tongue might influence the reading of English within the different bilingual groups.

To account for the diversity and complexity of the bilingual background, a systematic research framework is employed that includes three components to investigate the effects of script types between the two bilingual groups. First, all participants are required to fill in a detailed language background questionnaire, which helps us understand their bilingual profiles including their self-reported proficiency level, age of acquisition, frequency of usage of their known languages, etc. Second, the participants are tested with a series of neurocognitive measures including a variety of verbal tests in their mother tongue and in English (e.g., vocabulary, reading, phonological awareness, and spelling). These behavioural tests allow us to investigate the extent to which reading in English may be influenced by the familiarity of the writing system of the mother tongue, and vice versa. Finally, the participants are invited to undergo a neuroimaging session, during which we acquire their structural scans of the brain and measure their brain activity while they perform a reading task in each of their languages. The neuroimaging data will enable us to elucidate the neural basis of reading in the bilingual brain across individuals with different known script sets. This allows us to compare neural reading routes between the groups whose languages differ in orthographic depth. In addition, we can examine possible moderating factors that differ across individuals such as their age of L2 acquisition and proficiency level. Taken together, this project will provide an integrated neurocognitive model of reading for bilinguals taking into account their language profiles.

3.5 Implications and Future Research

Understanding the diverse linguistic profiles as well as how they shape the neurocognitive mechanisms underlying language and reading abilities provides important implications for many societies with increasing bilingual/multilingual populations. For education, delineating the similarities and differences between processing the two languages in bilinguals could help develop effective training programmes tailored for each language. Given the linguistic properties, the manifestation of difficulties in processing one language might differ from that of the other. This suggests that reading or language remediation programmes might be more effective if they take into account the specific properties of each language. For clinical applications, as the neural networks involved in language and reading for bilinguals might vary depending on the properties or proficiency of each language, clinicians could consider the language background of the patients during pre-surgical planning for tumour dissection or post-surgical prognosis for patients whose lesions might compromise brain regions involved in language processing.

Our ongoing efforts in profiling bilinguals and elucidating the neurocognitive mechanisms of bilingualism have opened the way for future research. For instance, more-detailed investigations of the particular language mixes that children are exposed to at different time points are needed to better link language mixes at a given time with multivariate language proficiency outcomes. While our Effective Biliteracy Project with adults would provide a better understanding of the bilinguals' neural reading networks, we could only correlate the differences in the neural networks with individuals' language profiles. However, we would not be able to delineate how and when the different script types influence the neural networks. Therefore, the investigation needs to be extended to younger bilingual children who have just begun to read. By examining how the neurobiological basis of reading and language processing develops in early childhood and how it is influenced by the acquisition of different script types, we will be able to obtain a more comprehensive picture of the impact of bilingualism on learning.

3.6 Conclusions

The research illustrated in this chapter has pointed out large variabilities in the language profiles of bilingual learners and has suggested that the multiple script types used by bilinguals impact the neurocognitive basis of language and literacy skills. These investigations provide important implications for the increasing bilingual/multilingual populations around the world and pave the way for future systematic investigations into other age cohorts and bilingual mixes. To conclude, this chapter establishes the significance and importance of our thriving efforts in multilingual research for the science and policy in education.

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Part II
Psychology and Education

Chapter 4
A Preliminary Study on the Impact of a Brief Online Growth Mindset Intervention on University Students

Betsy Ng, Jiahua Shi, Shen-Hsing Annabel Chen, and William Wei Ning Chen

Abstract This study utilized a brief online growth mindset intervention to promote students' cognitive, academic and behavioural skill development. It explored the strategies developed by Dweck and colleagues to promote a growth mindset in university students. There were 120 university students who participated in this study and were randomly divided into two groups: one group primed with a growth mindset while the other primed with a fixed mindset. Participants who underwent the growth mindset intervention showed a significant increase in their growth mindset and a significant decrease in the fixed mindset, indicating that the positive impact of the growth mindset. Their mastery approach and academic resilience scores also improved significantly. Implications of this study were discussed and recommendations were suggested for applied education research and future studies.

Keywords Growth mindset · Intervention · Fixed · Mastery · Academic resilience

4.1 Introduction

A growth mindset enables students to monitor and interpret their actions when their learning process goes awry. Students with a growth mindset can pursue their goals effectively, thereby boosting their motivation and academic performance (Donohoe, Topping, & Hannah, 2012). Students who embrace a growth mindset will ask questions such as "How can I improve my understanding?" or "What can I learn from this course?" instead of "I was a born loser" or "I can never excel in whatever I do". The growth mindset intervention will help students to cultivate a sense of mastery (Dweck, 2006).

As most empirical studies were conducted in the States (e.g. Donohoe et al., 2012), the key question is whether the brief growth mindset intervention could work in other academic settings. In addition, since there is limited research on growth

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mindset intervention in higher education, it is important to investigate the effects of growth mindset on students' learning and motivation in higher education.

In this preliminary study, university students were primed with either a fixed mindset or growth mindset through an online introductory course. Through this online introductory mindset course, the undergraduates learnt about the roles of a fixed or growth mindset in monitoring their own learning and staying attuned to their actions. This study explored whether the brief online growth mindset intervention would increase student motivation and academic resilience as well as promote mastery of learning.

4.2 A Review of the Key Constructs in This Study

4.2.1 Mindset

Mindset is defined as one's beliefs (Dweck, 2006). According to Dweck (2006), individuals generally embody one of two mindsets: either fixed or growth. A person with a fixed mindset views intelligence and talents as naturally determined and unchangeable (i.e. entity beliefs) whereas a person with a growth mindset views talent and intelligence as malleable and incremental (i.e. incremental beliefs), and therefore intelligence can be nurtured and improved (Dweck & Molden, 2005).

Growth mindset is also linked to a mastery approach to learning (Donohoe et al., 2012). Learning with a mastery approach focuses on the development of competence, knowledge and skills based on one's prior achievement (Elliot & McGregor, 2001). On the other hand, a learner who adopts a performance-approach tries to surpass others in terms of achievement. Learners with a growth mindset will embrace a mastery approach, whereas learners with a fixed mindset will likely adopt a performance-approach. In short, individuals with a fixed mindset believe that their traits are inherent and nothing can change them. Those with a growth mindset believe that traits are not static and can be nurtured.

Dweck's studies show that around 40% of US students display a growth mindset and 40% a fixed mindset, while the remaining 20% show mixed profiles (Boaler, 2013). When students undergo an intervention to move from a fixed to a growth mindset, they immediately start performing better at higher levels in school (Dweck, 2006). An online programme targeted at middle school students (aged 11–13) was developed for student intervention which exposed the students to the plasticity of the brain and the impact of brain exercise on the growth of intelligence.

4.2.2 Empirical Research on Growth Mindset

Generally, people are born with a love for learning (Dweck, 2006). However, situational factors or past learning experiences may undermine one's love of learning. According to Dweck (2006), individuals with a fixed mindset are likely to disagree that love of learning is an inherent trait. Those with a growth mindset will picture their brain forming new connections as they learn new things and meet the challenge. Learners with a growth mindset tend to embrace lifelong learning and the joy of incremental personal growth. In addition, they do not see their intelligence or personality as fixed traits. They will mobilize their resources of learning without being defeated by the threat of failure. Universities should strive towards cultivating academic resilience and mastery in our undergraduates, preparing them to meet the challenges in the real working world.

Empirical studies revealed that a growth mindset has positive effects on student motivation and academic performance (e.g. Blackwell, Trzesniewski, & Dweck, 2007; Dweck, 2009). Recent research also showed that mindset is related to student outcomes and behaviours including academic performance, engagement and willingness to attempt new challenges (Vedder-Weiss & Fortus, 2013; Yaeger & Dweck, 2012). Numerous studies have shown the effects of growth mindset interventions on students' achievement, at all ages. A growth mindset intervention was especially impactful with student outcomes of particular subjects such as science and mathematics (Dar-Nimrod & Heine, 2006; Good, Aronson, & Inzlich, 2003; Grant & Dweck, 2003).

According to Dweck (2009), teaching growth mindset to junior high students resulted in increased motivation and better academic performance. Her findings revealed that students in the growth mindset intervention group outperformed those in the control group (who received excellent training in study skills), indicating improved learning and desire to work hard. The growth mindset intervention teaches students that intelligence is not a fixed quality (Aguilar, Walton, & Wieman, 2014). Intelligence can be nurtured through challenging tasks as intelligence grows with hard work on challenging problems. Hence, encouraging a growth mindset can improve the academic performance of college students (Aronson, Fried, & Good, 2002; Grant & Dweck, 2003) and middle school math students (Blackwell et al., 2007). Such interventions could provide similar benefits to our university students.

On the contrary, Donohoe et al. (2012) conducted an online intervention (Brainology) to a number of young students in Scotland. The intervention led to a move towards a growth mindset in the participants, but there was no significant difference in the students' academic performance one year later. One quasi-experimental study examined how mindset impacted gifted (talented) students and regular education students. The study reported that gifted students were more likely to believe that their intelligence in science was malleable than were their classmates in the regular education setting (Esparza, Shumow, & Schmidt, 2014).

In another study conducted in the USA, Lin-Siegler, Ahn, Chen, Fang, and Luna-Lucero (2016) used a mixed-method study on high school students with a different intervention. The experimental group of students received an intervention with the use of struggle stories of eminent scientists while the control group received stories on great discoveries made by the scientists without the struggles. Results showed that participation in the struggle story conditions improved science learning, relative to that of the students in the control condition.

Only one unpublished MA dissertation was found on studying mindset in Singapore (Tan, 2016). The qualitative case study involved a small group of families who homeschooled their children. One of the study's findings is that the homeschooled environment provided avenues for growth mindset. Another research conducted on gifted primary and secondary school students in Hong Kong reported that healthy perfectionists seemed to hold more strongly the growth mindset and unhealthy perfectionists the fixed mindset (Chan, 2012).

The abovementioned empirical studies on growth mindset focused mainly on junior high or secondary school students, and were mostly conducted in the United States. As there are limited growth mindset studies in university settings and Asian contexts, this study attempts to address this gap. In this study, a fixed mindset is operationalized as the entity belief towards academic performance, whereas a growth mindset is defined as the incremental beliefs that students can improve their academic performance.

4.2.3 Mastery Goal Orientation

Related to the mindset of learning are the types of learning goals. A person who sets mastery goals focuses on the development of competence through task mastery (Elliot & McGregor, 2001). Competence is at the conceptual core of the achievement goal construct and it is defined in terms of the referent or standard that is used in performance evaluation. Learners with mastery approach goals try to master learning tasks and they do their best to completely acquire the subjects and mastery of the tasks. On the other hand, a person with performance goals desires to do well and to be positively evaluated by others.

Hidiroğlu and Sungur (2015) studied 153 seventh-grade students attending urban public schools in Turkey through the administration of the Achievement Goal Questionnaire and Engagement Questionnaire. Results from a series of multiple regression analyses revealed that mastery approach goals were significantly and positively related to all aspects of engagement in science, while mastery avoidance goals were found to be positively associated with cognitive engagement. Students adopted avoidance goals to avoid failure and avoid looking incompetent. Another study by Kayis and Ceyhan (2015) on achievement goals was also conducted in Turkey, but based on responses from 1509 university students. The findings showed that students generally adopted the mastery approach at a high level, mastery avoidance at a medium level, and both performance-approach and performance-avoidance at a low level.

One UK-based study (Remedios & Richardson, 2013) examined the achievement goals, approaches to studying and academic attainment in 1211 distance learners.

The findings confirmed that mastery goals were positively associated with deep and strategic approaches to studying and negatively associated with a surface approach. Performance goals showed only weak associations with approaches to studying. Performance-approach goals were positively related to attainment, performance-avoidance goals were negatively related to attainment, but mastery goals were unrelated to attainment.

Another study (Soltaninejad, 2015) aimed to examine the relationships between achievement goal orientations and learning strategies. Three hundred and fifty students from two public high schools in Iran took part in the study. The Achievement Goal Orientations Scale (AGO; Elliot & McGregor, 2001) and Learning Strategies Scale (Kember, Biggs, & Leung, 2004) were used. In the correlational analysis, mastery goals predicted positive deep strategy and performance goals predicted positive surface strategy in a positive way. According to the results, achievement goal orientations (except the relationship between performance-approach and deep strategy) were significant determinants of learning strategies.

The abovementioned empirical studies on mastery goal orientation focused mainly in high school settings. None of these studies were conducted in the Asian educational contexts. Based on our existing knowledge, there is no study that utilized both mindset and goal orientation in university settings. This study examined the relationship between mindset and mastery goal orientation.

4.2.4 Academic Resilience

Academic resilience refers to a student's capacity to overcome acute or chronic adversities that are seen as major assaults on educational processes (Martin & Marsh, 2009). The Academic Resilience Scale (ARS), developed by Martin and Marsh (2006), is a measurement to assess how students deal with setbacks, challenges, stress, adversities and pressure in academic situations. The ARS was developed by Martin and Marsh based on samples of Australian high school students (2006, 2009). The validity and reliability of the ARS scale were examined in other parts of the world, including Turkish high schools (Kapikiran, 2012) and Egyptian university (Khalaf, 2014). The results of the exploratory factor analysis for both studies showed that the ARS scale is valid and reliable. Martin (2013) studied academic buoyancy (i.e. a student's capacity to overcome setbacks and challenges) and academic resilience on 918 Australian students from 9 high schools. His findings showed that academic buoyancy and academic resilience represented distinct factors sharing approximately 35% variance. Furthermore, academic buoyancy was more salient in negatively predicting low-level negative outcomes whereas academic resilience was more salient in negatively predicting high-level negative outcomes.

4.2.4.1 The Present Study

Based on the findings in the literature, this study is premised on a few assumptions about the potential benefits of a growth mindset. As educators, we could send messages that enhance student motivation and a sense of mastery approach. In addition, students could be given the opportunity to reflect on their mindset at various stages of life and explore the strategies developed by Dweck and colleagues to promote a growth mindset. Intervention could be tailored to address students' vulnerabilities in cognitive regulation and metacognitive beliefs about ability. Such interventions could potentially provide beneficial outcomes to our university students. In this study, the key rationale of the brief online growth mindset intervention is to equip students with relevant strategies and embrace a growth mindset. The main research question is to investigate whether the brief online growth mindset intervention was effective in equipping students with relevant strategies and nurture a growth mindset. The hypothesis is that growth mindset intervention would lead to positive effects on growth mindset, mastery of learning and academic resilience. This study aimed to bring in a research-based approach to develop students' abilities through their effort and learning. Although this study was considered preliminary, it would lead to a long-term impact on teaching and learning at the university level. The significance of this study includes knowledge contribution to the field of higher education as well as enhancement in the quality of students' learning. Eventually, the growth mindset intervention may extend to faculty and teaching staff to improve the quality of their teaching.

4.3 Methods

4.3.1 Participants

The data collection reached out to 120 undergraduates (age $M = 20.7, SD = 1.80$) who registered for the Research Psychology Programme at the Nanyang Technological University, Singapore. The sample comprised 44 males and 60 females (16 did not state gender).

Ethics clearance was obtained from the university ethics review board. Participants were briefed on the purpose of the study and the confidentiality of their responses was assured. Data were extracted from the online questionnaires (in English), which took about 15 min to complete. The questionnaire was administered to students before and after the online introductory mindset course.

4.3.2 Procedure

This study was advertised on the university research programme, which comprised mainly first-year students taking a psychology course. Two computer laboratories were used for two research conditions, namely, the intervention condition and control condition. Students in the intervention condition were primed with incremental beliefs via the introductory growth mindset course, whereas students in the control condition were primed with entity beliefs through the introductory fixed mindset course. Students in the control condition were considered as the wait-list group because they were given access to the online growth mindset course after one week. All 120 participants who signed up for the online introductory mindset course were not aware of the group they were assigned to.

All participants had given informed consent and they then completed the baseline questionnaires, hosted on the Qualtrics online survey platform. After the completion of the baseline questionnaire, participants started the online introductory course immediately. After the completion of the online introductory course to the growth mindset, students in the intervention condition completed the post-questionnaire. Students in the control condition followed a similar procedure: completed the post-questionnaire after going through the online introductory course to the fixed mindset. Those who were assigned to the control condition were informed that they could access the online introductory growth mindset course in one week's time.

The research design of the online growth mindset intervention was adapted from a recent study by Donohoe et al. (2012). The contents of the online introductory course are tailored according to Dweck's mindset theory (Dweck, 2006, 2007). An introductory course to growth mindset took place with the intervention group, while an introductory course to a fixed mindset took place with the control group. Both sessions ran concurrently in two separate, quiet rooms. Each session took about 40 min, including the attempt of a short quiz with 5 multiple-choice questions at the end. The short quiz was to test their understanding of the online introductory mindset course. The following sections describe the two conditions for the present study.

4.3.2.1 Intervention Condition: Growth Mindset

The introductory growth mindset course included the following contents (Dweck, 2007):

Students with a growth mindset believe that their abilities can be developed, and so their major goal is to learn. For instance, students tend to focus more on learning for mastery than their performance: "It's much more important for me to learn things in my course than it is to get the best grades". Although these students care very much about doing well in university, they put a premium on learning, leading them to earn higher grades. In other words, the cardinal rule of the growth mindset is to 'learn'. In addition, the growth mindset comes with three more rules that help students reach their goals.

1. Take on challenges.

Students will be offered a choice to take on a challenging task that they can learn from. Learners with a growth mindset will take up tasks that stretch their abilities and teach them new things.

2. Work hard.

Rather than thinking that effort undermines ability, learners with a growth mindset believe that effort enhances ability: "The harder you work at something, the better you'll be at it".

3. Confront deficiencies and correct them.

Students with a growth mindset are eager to remedy their deficiencies. They may be disappointed by poor performance, but they will deal with it directly.

4.3.2.2 Control Condition: Fixed Mindset

The introductory fixed mindset course included the following contents:

Students who believed in fixed intelligence tend to limit their academic performance. The three rules associated with a fixed mindset that will undermine the way of learning are listed as follows.

1. Don't make mistakes.

Students in a fixed mindset tend to think that mistakes or setbacks mean they lack ability. For instance, students with a poor grade in a new course would think that they are not good at that subject. They are likely to drop that course. Similarly, students in a fixed mindset believe that if they had the intelligence, it would carry them straight through to perfect performance. Anything less spells inadequacy and this is why many talented students lack confidence in themselves.

2. Don't work hard.

Students in a fixed mindset believe that hard work signalled low intelligence and their effort is a sign of limited ability. To students with a fixed mindset, it does not matter whether the coursework is new or difficult; their effort is a sign of limited ability. The idea that high effort equals low ability is one of the worst beliefs students can have. It is virtually impossible to do anything worthwhile without sustained effort.

3. If you make mistakes, don't try to correct them.

The learner with a fixed mindset does not provide good recipes for recovering from setbacks. Setbacks indicate a lack of ability and, in the fixed mindset, that lack of ability is permanent. Having a fixed mindset limits students' learning as they tend to avoid making mistakes and working hard. When they make mistakes, they do not try to correct them. Students with a fixed mindset are likely to focus on whether they get the answer right or wrong, without paying attention to what the right answer is or why their answer is wrong. Such an approach will not foster intellectual growth.

4.3.3 *The Instrument*

Students rated the items on a scale of 1 (‘strongly disagree’) to 7 (‘strongly agree’) for the following measures.

4.3.3.1 The Mindset Rating Scale

The Mindset Rating Scale measured students’ mindsets about the malleability of intelligence. The 16-item mindset rating form consisted of 8 statements related to a growth mindset and 8 statements with a fixed mindset (Dweck, 2006). Students who rated ‘7’ (‘strongly agree’) for statements like “intelligence is something that cannot be changed very much” and “you can learn new things, but you can’t change a person’s intelligence”), indicated having a fixed mindset, whereas those who rated ‘1’ (‘strongly disagree’) were categorized as having a growth mindset.

4.3.3.2 The Achievement Goal Questionnaire (Mastery Scale)

The mastery goal orientation scale was a 6-item measure from the Achievement Goal Questionnaire (AGQ; exclude avoidance scales; Elliot & McGregor, 2001). An example of the statements was “It is important for me to understand the content of this course as thoroughly as possible”.

4.3.3.3 The Academic Resilience Scale

The Academic Resilience Scale (ARS; Martin & Marsh, 2006) was a 6-item measure for students’ resilience in academic settings. An example of the statements was “I think I’m good at dealing with coursework pressures”.

4.3.4 *Data Analysis*

After the survey, data were uploaded to the SPSS statistical package for subsequent analyses. Based on the students’ responses, the reliability and validity of the instrument were tested. Exploratory factor analysis (EFA) using principal component analysis as the extraction method and Oblimin (with Kaiser normalization) as the rotation method was conducted to examine the stability of the measurement model (see Table 4.1). Subsequent analyses included repeated measures to examine the effects of a growth mindset on student academic resilience and mastery of learning.

Table 4.1 EFA results for the 28-item instrument

	1	2	3	4
Fixed mindset (FM)				
FM1	0.854			
FM2	0.882			
FM3	0.900			
FM4	0.765			
FM5	0.651			
FM6	0.757			
FM7	0.720			
FM8	0.696			
Growth mindset (GM)				
GM1		0.638		
GM2		0.690		
GM3		0.611		
GM4		0.732		
GM5		0.845		
GM6		0.804		
GM7		0.862		
GM8		0.854		
Academic resilience (AR)				
AR1			0.610	
AR2			0.755	
AR3			0.706	
AR4			0.726	
AR5			0.649	
AR6			0.754	
Mastery approach (MA)				
MA1				0.799
MA2				0.725
MA3				0.772
MA4				0.772
MA5				0.617
MA6				0.579

4.4 Results

This study sought to bring in a research-based approach to developing students' abilities through their effort and learning. The brief online growth mindset intervention aimed to equip students with relevant strategies and embrace a growth mindset. The instrument in this study consisted of 28 items on four dimensions (or variables): fixed mindset; growth mindset; academic resilience; and mastery approach.

The descriptive statistics showed the mean scores for all variables. The mean difference between the pre- and post-test variables for growth mindset is greater than that of the fixed mindset. The effect size of this significant mean difference is also greater for the growth mindset than the fixed mindset. The effect size estimates of 0.10, 0.25 and 0.50 indicate small, medium and large, respectively (Richardson, 2011). The effect size for each variable would be described subsequently. Table 4.2 presents the descriptive statistics and significant within-group effects for each variable.

The reliability coefficients for the pre-measures are satisfactory: the Cronbach alpha for a fixed mindset is 0.93; growth mindset is 0.93; academic resilience is 0.81; and mastery approach is 0.83. Table 4.3 presents the Pearson correlations of the internal consistency and correlations of pre-test variables.

Similarly, the reliability coefficients for the post-measures are satisfactory: the Cronbach alpha of fixed mindset is 0.95; growth mindset is 0.95; academic resilience is 0.89; and mastery approach is 0.87. Table 4.4 presents the Pearson correlations of the internal consistency and correlations of post-test variables.

Correlational results showed some significant relationships among the four variables for pre- (r_1) and post-tests (r_2). Fixed mindset was negatively related to growth mindset ($r_1 = -0.79$, $p < 0.01$; $r_2 = -0.81$, $p < 0.01$) and mastery ($r_1 = -0.22$, $p < 0.05$; $r_2 = -0.46$, $p < 0.05$). On the other hand, growth mindset was significantly related to mastery ($r_1 = 0.27$, $p < 0.01$; $r_2 = 0.47$, $p < 0.01$), while mastery was positively related to academic resilience ($r_1 = 0.34$, $p < 0.01$; $r_2 = 0.22$, $p < 0.01$).

A 2 × 2 (time versus condition) repeated measures ANOVA was conducted for fixed mindset, growth mindset, mastery approach and academic resilience, respectively. There was a significant time effect, indicating an effect over time for the two groups. There is no significant group effect, indicating no difference between the two groups of participants.

One-way ANOVA showed a significant difference between pre- and post-test scores for all variables within each group (see Table 4.2). There was a decrease in fixed mindset ($F(1, 107) = 39.62$, $p < 0.001$); an increase in growth mindset ($F(1, 107) = 57.27$, $p < 0.001$); an increase in mastery approach ($F(1, 107) = 12.63$, $p < 0.05$); and an increase in academic resilience ($F(1, 107) = 9.233$, $p < 0.05$). Effect size analyses for partial eta-squared value (η_p^2) indicated the significant change between pre- and post-test scores of each variable: fixed mindset ($\eta_p^2 = 0.27$); growth mindset ($\eta_p^2 = 0.35$); mastery approach ($\eta_p^2 = 0.11$); and academic resilience ($\eta_p^2 = 0.08$).

One-way ANOVA indicated no significant difference in pre-test scores between the intervention and control groups: fixed mindset ($F(1, 107) = 0.842$, $p = 0.361$); growth mindset ($F(1, 107) = 1.319$, $p = 0.253$); mastery approach

Table 4.2 Descriptive statistics and within-group effect

	Fixed mindset group ($N = 49$)				Growth mindset group ($N = 60$)				Effect	
	Pre		Post		Pre		Post			
Variables	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*	η_p^2
Fixed mindset	3.56	1.12	3.50	1.15	3.90	1.15	2.80	0.94	39.62^{***}	0.27
Growth mindset	4.71	1.03	4.40	1.14	4.64	1.23	5.39	0.89	57.27^{***}	0.35
Mastery approach	5.87	0.75	5.73	0.66	5.80	0.80	5.95	0.59	12.63^{*}	0.11
Academic resilience	4.59	0.86	4.49	0.80	4.74	0.91	4.94	0.89	9.233^{*}	0.08

$^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$

Table 4.3 Correlations of pre-test variables

Variable	α	1	2	3
Fixed mindset	0.93			
Growth mindset	0.93	-0.79^{**}		
Mastery approach	0.81	-0.22^{*}	0.27^{**}	
Academic resilience	0.83	−0.18	0.15	0.34^{**}

Note $^{**}p < 0.01$; $^{*}p < 0.05$

Table 4.4 Correlations of post-test variables

Variable	α	1	2	3
Fixed mindset	0.95			
Growth mindset	0.95	-0.81^{**}		
Mastery approach	0.89	-0.46^{*}	0.47^{**}	
Academic resilience	0.87	−0.12	0.11	0.22^{**}

Note $^{**}p < 0.01$; $^{*}p < 0.05$

($F(1, 107) = 0.003, p = 0.955$); academic resilience ($F(1, 107) = 0.115, p = 0.736$). Effect size analyses for partial eta-squared value (η_p^2) did not show significant change between pre- and post-test scores of each variable: fixed mindset ($\eta_p^2 = 0.008$); growth mindset ($\eta_p^2 = 0.012$); mastery approach ($\eta_p^2 = 0.001$); and academic resilience ($\eta_p^2 = 0.000$).

4.5 Discussion

The purpose of this study was to explore the impact of a brief online growth mindset intervention on students' mindset, mastery and academic resilience in local higher educational contexts. It examined whether the brief intervention would encourage a growth mindset and if there was any significant change between pre- and post-test scores of each variable. As hypothesized, the growth mindset intervention led to positive effects on growth mindset, mastery of learning and academic resilience.

Correlational results were consistent with previous empirical studies on mindset and goals, such that learner incremental belief (i.e. growth mindset) relates to learner learning goals for mastery (Lou & Noels, 2016; Karwowski, 2014). Our findings revealed that learners primed with incremental beliefs were more likely to set mastery approach goals and to be more resilient in academic contexts than those who primed with an entity belief (i.e., fixed mindset).

Both fixed and growth mindsets were negatively correlated and the strength of this association was strong, suggesting that learners are likely to have a conflicting degree in beliefs that are at the two extreme ends of one continuum (Karwowski, 2014). It is unlikely that a learner can endorse both incremental and entity beliefs to the same degree. When the learner endorses incremental belief more than entity belief, he or she may value the effort required to learn and to set learning goals for mastery and thus react more persistently when coping with barriers (Lou & Noels, 2016). Being more persistent in their learning, they develop academic resilience and perceive the positive role of failure in improvement (Rattan, Savani, Chugh, & Dweck, 2015).

In the fixed mindset group, there were significant decreases between the pre- and post-test scores for all variables after the intervention. The growth mindset score decreased more than the fixed mindset score over a short period of intervention. Likewise, both the mastery approach and academic resilience scores decreased over time, indicating the negative impact of the fixed mindset (Dweck, 2008).

In the growth mindset group, there were significant changes between the pre- and post-test scores for all variables after the intervention. The fixed mindset score decreased but the growth mindset score increased over the short period of intervention. Likewise, both the mastery approach and academic resilience scores increased over time, indicating that the positive impact of the brief online intervention. Consistent with the findings by Donohoe et al. (2012), participants who underwent the brief online growth mindset intervention showed a significant increase in their growth mindset and a significant decrease in the fixed mindset, indicating that the belief that intelligence is malleable. Their mastery approach and academic resilience scores also improved significantly. Embracing a mastery approach orientation is important in learning as students will do their best to acquire the subjects and develop their competence through mastering the given tasks (Elliot & McGregor, 2001). Academic resilience is also an important construct in higher education, particularly when university students are experiencing stress in their course of study. Building the students' capacity to overcome acute or chronic adversities during their years of university study will equip them with the relevant coping strategies to deal with setbacks, challenges and stress in their academic situations (Martin & Marsh, 2006).

Based on the effect sizes, it is significant that the growth mindset supported the improved scores on the learner incremental belief, mastery and academic resilience. The fixed mindset scores in the growth mindset group decreased significantly, indicating that students endorsed incremental belief more than entity belief. Incremental and entity beliefs share an inverse relationship. As supported by previous empirical findings (e.g., Gunderson et al., 2013), entity belief score is likely to decrease when the incremental belief score increases. However, the effect size of a growth mindset on academic resilience is small, suggesting that the duration of the intervention may be too short for learners to develop resilience. It takes time to develop one's persistence and resilience over the learning process (Yeager & Dweck, 2012). Hence, it may not mean that students with mastery of learning will inherently develop academic resilience. In addition, students with mastery goal orientation may not have the resilience to cope with challenges when they encounter barriers to learning.

4.6 Implications and Limitations

The implications of the growth mindset are profound because the ability to learn effectively and develop resilience is dependent on individual beliefs. Students need to have the belief that ability is malleable and it can be developed. By having this self-awareness about their ability to develop a productive growth mindset, students are likely to engage in challenges and they are not afraid to make mistakes. Students usually avoid challenges and they prefer easy tasks to challenging ones, knowing that they would succeed on easier work. However, making mistakes is an aspect of learning and research has shown that mistakes are valued as learning achievements (Boaler, 2013). When students think about why something is wrong, new synaptic connections are formed in their brains (Dweck, 2012). Students with a fixed mindset would regard mistakes as an indicator of their low ability. It is recommended that universities should provide workshops or seminars to constantly communicate messages of growth mindset to students about their ability and resilience in the face of learning failures.

The current findings suggest that the application of the online growth mindset intervention facilitated students' academic resilience and mastery for learning in university settings. However, there are several limitations to consider in this study and they may provide some direction for future research. First, this was a preliminary study with a small sample size. A large sample size is needed before we could generalize the findings across university students. A future study could replicate the online growth mindset intervention with a large student population. Second, self-report measures were used and they were unable to uncover the process of mindset shift or change. Additional data sources could be included in further research. Third, the contents for the brief online growth mindset intervention was created using Dweck's mindset strategies and framework. Strategies that are relevant to academic resilience could be included to better equip students with the knowledge to cope with stress in their course of study and examination. Despite these limitations, the findings revealed some significant results that provide relevant insights for practitioners and researchers. It also offered some useful considerations for future studies.

4.7 Future Research

This preliminary study offers a useful approach to supporting university students' growth mindset and academic resilience. Further research will benefit from the continued development of the online mindset intervention to connect academic resilience and learning for mastery. Future research may develop strategies for academic resilience on university students. Finally, the current findings supported the short-term changes in mindset although there was no follow-up to evaluate the sustainability of mindset change. A future study could include an additional time-point or perform longitudinal research to examine the long-term impact of the online growth mindset intervention. It will also be interesting to examine the mindset change of students in terms of performance within a given academic context.

4.8 Conclusion

This study aimed to investigate the effects of a brief online growth mindset intervention on university students' learning. It was found that participants in the intervention condition reported higher scores for growth mindset, mastery of learning and academic resilience, than those in the control condition. Findings in the present study also shed light on the relationships of growth mindset with a mastery approach and academic resilience in university students. They also provide some direction for future education research in intervention when seeking to promote and foster a growth mindset and motivation.

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Chapter 5
Negotiating Objects of Activity for Teacher Learning in a Professional Learning Community

Shien Chue, Chew Lee Teo, and Seng Chee Tan

Abstract Professional Learning Communities (PLCs) hold considerable promise for teacher learning in the workplace. In the context of teacher learning, a PLC is a community of teachers collaboratively engaged in critical inquiry and updating their teaching practices. It is a collaborative learning model that has the potential to propel teacher learning. This chapter uses Cultural Historical Activity Theory to analyse a case of a group of elementary school teachers working on lesson design using Knowledge Building (KB) pedagogy to enhance student learning. One interesting feature of such a community is how teachers accommodate the emergence of tensions and conflicts that challenged established pedagogical practices. Through the co-configuration of work activities in the PLC, we explicate how pedagogical decisions are constituted at the local level for classroom implementation.

Keywords Professional learning communities · Teacher learning · Knowledge building · Cultural historical activity theory · Pedagogical decisions

5.1 Introduction

Professional Learning Community (PLC) offers fertile ground for studying and enculturating innovative practices among teachers. As teachers share their expertise in PLCs, they construct new knowledge about instruction and content (Little, 2003; Stoll, Bolam, McMahon, Wallace, & Thomas, 2006). In fact, collaborative work in teaching involves problem posing and the articulation of practice (Horn & Kane, 2015). Teachers are positioned to learn from talking with colleagues and that there are opportunities for learning constituted in teacher workgroups (Tam, 2015). However, current attempts to identify the processes of teachers' knowledge

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construction of pedagogical practices are nested within activities organized for professional development (Horn, 2010; Little, 2003) and do not mirror the naturalistic environments in which teachers are engaged in as part of the authentic school context.

This case study focuses on teachers who were designing and implementing knowledge building pedagogy (Scardamalia & Bereiter, 2006) in a school. Knowledge building is generally understood as a discursive activity intended to enhance collective understanding (Bereiter, 2002). It requires participants to work collaboratively and take responsibility for learning what they need to know as they engage in deep discussions centred on problematized content (Cornelius & Herrenkohl, 2014). While much is known about how teachers and facilitators work together for knowledge building (Tan, Chue, & Teo, 2016; Orland-Barak & Tilema, 2006), less is written about how new innovations, in this case, knowledge building, become enculturated as part of educational communities and the shared repertoires and practices of teachers (Timmis, 2014).

In this chapter, we examine two cases of enculturation of teachers for the adoption of knowledge building pedagogy (Scardamalia & Bereiter, 2006): for engaging students in a collaborative investigation of scientific problems, and for group narrative writing activities during professional learning community meetings. Our work aims at developing an explanatory picture of sustainable knowledge building practices using Cultural Historical Activity Theory (CHAT). With a fine-grained analysis of naturally occurring interactions among teachers during PLC meetings, we can understand the affordances of professional communities for teacher learning and innovation in teaching practice. Critically, paying attention to the content of teacher talk, we can offer new insight into how teacher conversations shape and reshape the objects for creating knowledge building opportunities for their students. The guiding research question is "what patterns of interaction, organizational factors, and constraints influenced the sustained use of Knowledge Forum (KF) for classroom teaching?"

Following the analytical framework of de Lange and Lunc (2008), we analyse the dialectical nature of teacher conversations recorded over a period of one year. Our results highlight competing objects during PLCs as sustaining knowledge building practices, and that teachers as knowledge builders used knowledge building principles to monitor their work rather than being totally dependent on the mandated curriculum to chart their lesson design progress.

The following section reviews key research on knowledge building communities and the dialectical potential of CHAT to underscore our efforts in adding knowledge to the area of knowledge building within professional communities. We next highlight from our case study data conversation vignettes to demonstrate the multidimensional characteristics of workplace learning among our teacher participants. From our analysis, we believe that researchers and educators will be better placed to understand how members of a professional learning community can be doing knowledge building sustainably.

5.2 Literature Review

Knowledge building communities typically construct and progressively improve on ideas with representational artefacts. Knowledge construction in such collaborative settings is based on the assumption that members engage in specific discourse activities where the content of discourse is related to the construction of coherent and consistent knowledge (Greeno, 2003; Lave & Wenger, 1991). In this regard, much research has been conducted with respect to students' experiences in knowledge building (Scardamalia & Bereiter, 1994). Yet this cannot be said for teachers doing knowledge building as part of their professional learning.

Moreover, several conditions are needed to support knowledge building (Scardamalia, 2002). First, people need to work on knowledge problems that arise from attempts to understand the world. Second, they work with the goal of improving the coherence, quality and utility of ideas. They need to negotiate a fit between their own ideas and those of others and use the differences to catalyze knowledge advancement. Through asking questions, making statements elaborative or regulatory in nature, these conversational moves enable knowledge building (Hmelo-Silver & Barrows, 2008). Such discourse requires active participants in identifying knowledge problems and improving their ideas collectively (Duschl & Osborne, 2002). There is a lack of substantial empirical evidence on how these conditions influence teachers as they come together for knowledge building.

Our concern for teachers' knowledge building discourse is shared by other researchers. Educational reformers have argued that for teachers to be successful in constructing new roles, they need opportunities to participate in a professional community that "discusses new teacher materials and strategies and that supports the risk taking and struggle entailed in transforming practice" (McLaughlin & Talbert, 2001, p. 15). Traditional off-site teacher training workshops are criticized for being too removed from the authentic classroom contexts, lacking the transformative power to change classroom practices. In contrast, the development of a school-based teacher learning community (Stoll & Louis, 2007) offers teachers opportunities to work together in diverse and complex ways and engage in a process of being a professional teacher (Lave & Wenger, 1991). When diverse groups of teachers come together in discourse communities, they draw upon and incorporate one another's expertise to create rich conversations and new insights into teaching and learning. For example, Lee & Tan (this volume) demonstrate how learning analytics can be a tool for adult learners to critically examine their discourse for learning in an online knowledge building community. Similarly, there is a need to forge ahead to examine the knowledge building potential that resides in records of discourse among teachers in the course of their participation in professional learning community meetings. Consequently, our work has the potential to update collective repertoire of practices (Allaire, Laferrière, & Gervais, 2011) as we surface how teacher conversations can supply intellectual, social and material resources for teacher learning and innovations in practice.

Cultural Historical Activity Theory (CHAT) provides the theoretical tool for understanding the work of teachers as goal-oriented, collective and mediated (Engeström, 1999). A fundamental principle of this theory is that all human activity is oriented towards producing either material or conceptual things (objects). Activity as the unit of analysis is understood in terms of the interaction of multiple components of human activity, including rules, division of labour, community and artefacts that mediate a subject's ability to achieve the object (or intended outcomes) of their activities. Activity systems are also continually evolving through the dialectical contradictions between the different levels and elements of the system. For example in organizational studies of a self-managing team, the tension between manufactured goods as a source of pride and revenue is constantly in the collective focus of workers in their production arrangements (Barker, 2005). With contradictions understood as the dynamic tension between opposing forces in an activity system, subject and object are not separate entities but are mutually defining and clashing, resulting in new forms or adjustments to emerge (de Lange & Lund, 2008).

CHAT has the potential to research the sustainability of computer-supported collaborative learning practices in authentic educational settings (Timmis, 2014). Yet a critical review of the use of CHAT in classroom research revealed few studies that employed the deeper dialectical analysis of tensions and contradictions to analyse networks of activity systems with shared objects (Nussbaumer, 2012). This is not helped when CHAT is employed as guiding principles rather than used centrally within analysis (e.g. Siyahhan, Barab, & Downton, 2010). To tap on the explanatory power of CHAT, we need to undertake a dialectical analysis of the contradictions that emerge from the interactions of different elements and levels within the system (Roth & Lee, 2007).

5.3 Context

This work is part of a larger project that aims at sustaining a Computer-Supported Collaborative Learning (CSCL) environment through an online Knowledge Forum (KF) for knowledge building discourse as an educational objective both for teachers and students. As part of the implementation of knowledge building in the curriculum, our research team worked with a team of eight elementary teachers from Future State Primary School (pseudonym) to incorporate Knowledge Building principles in the design of their lower elementary science and English lessons.

Teachers met once weekly for two hours to design lessons. During their weekly meetings, facilitators sat in the meeting as advisors. These facilitators are former secondary school teachers with extensive knowledge and experience working with multiple schools on implementing knowledge building principles. As part of the field support, facilitators first provided training for teachers on the use of KF and its associated online learning environment before they met weekly to craft their lesson designs. Importantly, they catalyzed collaborative knowledge building for the teachers by helping with navigating the online forum and offering suggestions to teachers to read the online posts of their students. Subsequently, as teachers became more proficient technically with the KF platform, facilitators took on an observer role by listening in during the meetings.

5.4 Data Analysis

Data set for this chapter is drawn from a one-year period of recording and transcribing the PLC meetings of teachers from a primary (elementary) school in Singapore. Teachers met once a week for about two hours to discuss their lesson plans for both their English and Science classes. During the meetings, there was a mix of teachers who were proficient with the online learning platform as well as novice teachers attempting to understand and use knowledge building principles to design their lesson plans.

There were five stages of data analysis. The first stage entailed a thorough immersion of the researchers in the data at the onset, which included the transcription of video recorded data of teachers' weekly PLC meetings. Readings and re-readings of all transcripts with detailed notes were also created that classified the content of transcripts according to procedural and conceptual discourse. The procedural talk includes discussion on the logistics of lessons, venues, and distribution of work. Conceptual talk encompasses teachers' individual reflection and group discussion on how to teach particular science or English topics. The second stage involved reviewing and summarizing the historical level of analysis in order to understand the history of the curriculum and teachers within the school. This included writing knowledge building stories to understand the flow of lesson plans, and logging into the KF to follow the posts of teachers and their students. We also identified the intended learning outcomes and personal backgrounds of the teachers and facilitators. This included the articulation of the key elements and agents in the activity system through a mainly descriptive process.

The aim of the third stage was to analyse the data thematically into categories including history of the activity, cultural practices, interpretations of the object, tool/artefact mediation, temporal/spatial dimensions, division of labour and peer relations. These were used alongside data-driven categories to re-interrogate the data and problematize the dynamically evolving activities and structures of the activity system. As the stages of analysis were iterative, this stage provided an early indication of areas of contradiction and tension for further stages of analysis. Following on in Stage 4, how activities during PLC unfolded were analysed following the principles of interaction analysis (Jordan & Henderson, 1995). We discussed emergent meanings about the purpose of the teacher talk and focused on how an idea from one teacher would relate and influence the next teacher who spoke. With such a focus, we read the weekly transcripts horizontally to familiarize ourselves with the many content topics that were covered. We also read the transcripts vertically to observe how a particular topic was developed and built up over the weeks. In order to build up a transcript that could index knowledge building principles that the teachers have employed, we marked out transcripts and wrote them out as vignettes to support our understanding of the development of the teachers' PLC meetings. During the intensive group discussion of the data, we asked questions such as What is the trajectory of learning across the topic of "system"? How did the teachers plan on starting the topic of "system"? Did they begin with definitions or questions or case examples to trigger questions from their students? How did the discussion on system change mid-way? Did the teachers revisit the questions post by their students? Why are the English teachers focusing on stimulus-based conversations as a start for the use of KF? What is the progression? Were more topics introduced along the way? Such questions were useful in focusing our attention on the discourse of teachers during repeated readings of the transcripts. Ultimately at the final stage of analysis, findings were brought together to identify the opposition and misalignments through CHAT's theoretical underpinnings.

5.5 Findings

This section identifies competing objects as motivating/propelling the work of teachers as they worked and expanded on their teaching plans. Importantly, teachers struggled to establish shared goals and to incorporate KF into their lesson plans. The contradiction between a collaborative object (i.e. engaging students for knowledge building) and individual objects (i.e. implementing the mandated syllabus) reverberated through the data set. Importantly, tools, community, division of labour, relational agency mediated unfolding interactions over the one-year period, sustaining the use of an online KF platform for language and science classroom teaching. In effect, as the different objects competed for attention, it was over time that these objects were modified to become a collective object which created a community engaged in performing knowledge building to enable students to engage in knowledge building during curriculum time. We conclude by discussing how these examples of competing objects during PLC can constitute a key resource for teachers faced with the task of sustaining the use of KF for helping students make deep connections with mandated content knowledge.

5.5.1 Shaping Competing Individual Objects for a Shared Object

In this particular PLC session, there were eight teachers and one facilitator seated around a table to update and discuss the following week's knowledge building lesson plans. Senior teacher Patty began the session by sharing in detail the implementation of narrative writing in her class. The object (in this case, the intended goal, which can be both conceptual and practice) she offered in the discussion was a diagrammatic method of teaching narrative writing lessons. However, Andy, the facilitator interjected to comment that they were supposed to be creating a platform for students to reflect on the process of their writing. He subsequently quickly advanced his individual object, which is the goal of how one could be structuring the online KF with scaffolds by telling the teachers how tools in the form of keywords such as brainstorming, sequencing of events as forum headings could be weaved into an online KF. Teachers around the table resisted the idea with murmurings. Finally, Patty asked Andy if he was referring to offering scaffolds online for the entire process of story writing. Before Andy could answer, Patty reiterated that her students would often engage in writing with the help of diagrams rather than with structural writing scaffolds.

With competing objects made salient, Andy took a step back to ask Patty specifically how her use of scenario diagrams was supporting students in writing a complete narrative account. This created an opportunity for Patty to share the manner in which teachers were using pictures of events to encourage students, as a class, to brainstorm story ideas for the entire storyline from the beginning to the ending of the story as well as engaging students in writing portions of the story to share with the whole class. Andy picked up the "whole class" idea and suggested that students can be "collectively, going in (KF) to brainstorm and build on one another's ideas." In attempting to align their different objects for a practical outcome, Patty asked Andy how students could be building on one another's ideas when ideas are anticipated to be diverse. Andy aligned his object of structuring online scaffolds by offering examples at the sentence level for Patty and her teachers to demonstrate how students could be building on an idea with different ways of expression. This practical contribution reduced tension and drew Patty back to consider Andy's object of offering structural writing scaffolds online. However, this consideration led Patty to modify Andy's initial goal of creating online scaffolds by asking if it was possible to modify the scaffold to guide students into writing a concerted ending and if teachers could also modify the scaffold by modelling for students in KF, how ideas could be built up. At this point in time, Andy modified his initial object of structuring online KF to offer a suggestion that incorporated Patty's initial diagrammatic idea of guided writing by suggesting that the teachers could offer sentences as examples for knowledge building alongside the guiding pictures. With the shared object now as one of putting up pictures and guiding sentences in KF, it was interesting to note that a junior teacher Kamal volunteered to upload the pictures.

While it may seem like a shared object was finally binding all the participants of the PLC, it was not for long. As Kamal was retrieving the pictures from his computer, he raised the issue that offering students diagrams to support their writing did not seem like a thematic approach for narrative writing. His comment did not seem to affect Patty. She continued to speak to the rest of the teachers in the PLC that they would post up the theme "a challenge" for the students with structural scaffolds about when and where challenges could be encountered. While this seemed to signal a collective goal as all teachers were listening in, Andy was unable to align himself towards their collective object. He interrupted Patty to ask how the theme "a challenge" could be depicted with diagrams.

Consequently, a diagram of examination results was projected onto the screen, and teachers nodded their heads in agreement that it represented the theme of "challenge". However, Andy commented that teachers had to focus on structural processes of writing which required brainstorming and implied pictures would restrict writing to only a "personal recount" of events. His proposed object of focusing on structural processes of writing was met with resistance from the teachers who explained how the pictures were springboards for students to brainstorm about challenges. While Andy apologized for not understanding how the picture could support the writing process, he challenged the teachers by demanding a rubric to access students' writing if teachers were going to rely on diagrams for the writing lessons. In doing so, this new object of "rubrics for assessing writing" resulted in teachers questioning if they should be focusing on the content or language aspect of narrative writing.

Andy subsequently proposed "natural disaster" as a theme and invited teachers to brainstorm on it together with him. In doing so, teachers and Andy were brought back together as a community to achieve the collective object of "brainstorming on the theme of natural disasters." However, the teachers continue to express their keenness to want to experiment on how diagrams would affect the quality of brainstorming for writing ideas, and commented that they should do an experiment. Hence, Patty quickly announced that she would have diagrams related to the theme of "challenge" to guide students' writing on the KF, while another teacher, Pricilla, volunteered to conduct the same lesson using KF without diagrams for the students.

While working towards the shared object of "structuring an online KF narrative writing session using both keywords and diagrams," it can also be observed that individuals drew upon different tools and knowledge in their individual activity system and as soon as an intermediate shared goal is reached, the object escapes and must be reconstructed by means of questioning, demonstrating how tools (materials or conceptual) relate to the new goals. Following how Patty questions Andy's object alongside Andy's tit-for-tat response to her questions, individual objects morph to become a shared object that utilizes diagrammatic and conceptual tools to achieve the goal of creating an online KF narrative writing session for students. This final outcome of experimenting with the effects of doing KF with and without diagrams in their lesson plans illustrates how tensions were at the heart of the human activity of learning and improving one's own pedagogical practices (Fig. 5.1).

5.5.2 Co-creating a Shared Object

During PLCs, teachers design lesson plans for their science classes as well as English language classes. The next example is drawn from a segment of the analysis where a novice teacher was sharing her approach to teaching science. In crafting her object of activity, Eslin, who has only a few years of teaching experience, revealed her intentions to post students' ideas about the topic of systems of living things on KF:

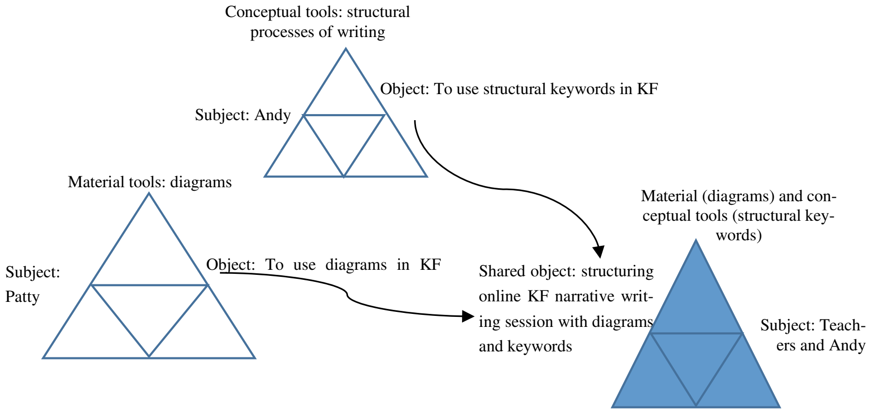

Fig. 5.1 Negotiation for a shared object of structuring an online Knowledge Forum (KF) narrative writing session with tool selection for modification of individual objects

> For me, I started on the class blog first because I was unsure of KF. I posted in the blog "plants are non-living because they do not move from place to place" and the other one is "clouds are living because they move and they grow in terms of…" Most of the students' responses are quite in depth. So I plan for the next class I will show them their blogs and ask them to continue asking questions on KF.

At this point, Patty suggested tentatively that Eslin may not want to rush students into putting up their ideas on KF. Using a first person stance to contrast her approach from Eslin, Patty cushioned the impact of offering direct instruction for Eslin:

> I think for me, I would not rush into putting up notes on KB. I probably would want my children to understand the scaffolds and I will spend time to ask them what it means and do a teacher demonstration to give students a chance to first practice. It is quite a big transition from class blog to the KF. As the interface is quite different, it takes times for the children to adapt to it. Actually for our class, it took us half a year because we could not move the kids to the actual KF. So to move students to KF is a very good idea, but perhaps my suggestion would be to spend more time on teacher demonstration.

Eslin interjected at this point to restate her intentions of "using some of the students' postings to show" on KF. However, she received another similar response from yet another senior teacher, Yasmine, who jumped into rephrase Patty's previous suggestions in more concrete terms:

> Actually what I did previously with my class was that I not only show them the different functions in KF, I also showed examples on what and how they can phrase their ideas. So initially I will limit students to two scaffolds each, and when they became more comfortable with KF, they posted more. It is important to tell them how to phrase their questions and to teach them how to write their note so readers will know what they are writing about. So first few lessons, you have to do all these basic first.

Rejecting Yasmine's attempt to relate in a hierarchical manner, Eslin did not acknowledge Yasmine's concrete suggestion of modelling how to use the KF for students. Instead, Eslin maintained her object of "getting students to ask questions on KF" with plans to "just take the notes that are here." This elicited an immediate response from Patty as she persisted to shape the activity of Eslin by suggesting alternative methods of using students' notes:

> That is why I am thinking maybe you can use these notes. The more they add on, the tougher it is for you to manage. So with these ideas you can take them to demonstrate for the children. And last week you were talking about the cloud system right?

Patty's reference to the cloud system helped to ground the conversation with a specific example (technology and material tools for shaping a shared object) as this led to Eslin projecting students' posts for the cloud system on the screen for the teachers to view. With Patty's request for clarification about the cloud system, Eslin now had the opportunity to verbally map out her teaching intentions, which clarified her object of activity for the other two teachers:

> This student was posting on why clouds move. This student, Yumi, said it is actually the wind. So I will ask the class to think if this note is considered as a theory or new information. And I will use Priscilla's post that a cloud does not need air food and water as an example of new information.

This offered Patty a good opportunity to reiterate her initial suggestions for modelling the use of KF for students. Patty suggested that Eslin could use the notes to ask other children if it was a theory, new information or was it something that they wanted to understand. Patty also suggested that Eslin could get her class to build on the characteristics of living things and to offer praise for students who ask good questions.

Eslin agreed with Patty's concrete suggestions this time. She proceeded to shape her object from "getting students to ask questions on KF" to "modelling the use of KF to structure students' thinking" by repeating her teaching intentions which incorporated elements of Patty's suggestion (shared object).

> So I do not need them into the lab for KF. So I will just teach them that kind of things, the categories of notes. For example last Friday, most of the students posted "agree" in KF, and so I will ask them to continue to elaborate on their post as they are not putting knowledge together when they are not elaborating on their friends' notes.

Recognizing that Eslin had understood the need to spend some time on helping students learn how to post their notes, Patty continued:

> These students have a personal opinion when they are able to say " I don't agree" so perhaps we can get them to reason first, you can actually open the note, show them and do a KB talk, just do a KB talk with them and see what questions they have.

Knowledge of how to handle students' posting deepened as Eslin continued to reveal another student post that read "plants actually do move towards the sun" and that the student had mentioned using a time video to investigate the phenomenon. Eslin then mentioned that she would use his post to illustrate how ideas can be supported. Patty expanded their shared object of "modelling how to do knowledge building" to "planning a knowledge building science lesson on the topic of living thing" by subsequently revealing how she had previously taught that similar topic:

> Slightly different, but I had pictures of seeds and use it as trigger to ask them why is it a non-living thing and had them test it out by growing seeds. They grew different types of seeds and recorded the cycle and they realized that seeds actually needs air, water and grow and after two weeks, we put up the notes and move the lesson.

Patty continued to suggest that Eslin could bring in a terrarium which was a mini garden cultivated within an enclosed glass container, as an artefact for students to observe and comment on plant growth.

In this instance, Eslin had initially set forth the object as a teaching plan to utilize students' posting for learning about living things. With Patty and Yasmine sharing their differing pedagogical approaches, it was challenging to negotiate for a fit between Eslin's idea of what to do with students' posts and the ideas of Patty and Yasmine who both had advised on focusing on modelling for students the mechanism of KF. However, as their conversations become more focused upon students' posts, the relations among the teachers became horizontal with visible knowledge advancement as Eunice gained additional knowledge on how to modify her teaching plan, gaining consensus from senior teachers that her knowledge building plan for classroom implementation was sustainable. With a shared object of focusing on students' posting to teach the topic of living things, the two senior teachers offered additional pieces of knowledge about the specific activities they had conducted with their students in the classroom which were valuable resources for Eunice to tap upon as a relatively new teacher to KF. With the teachers acting on the resources offered to each other within the action of discussion, the object expanded from dealing with students' posting to charting a lesson plan for using KF to teach the topic of plant systems.

5.6 Discussion

The results of our analysis locate shared objects as shaped within conversations of teachers during their weekly PLC meetings. Moving from dealing with different objects for creating a shared object of scaffolding narrative writing, Patty and Andy were initially observed to be reacting to each other's problems (objects). However, by drawing upon different tools of preference, it was possible for the teachers to shape a collective object for structuring the narrative lesson on the online KF for their students.

Contesting interpretations of Eslin's object by the rest of the more experienced teachers were salient in the episode described above. As Eslin set forth her personal ideas about students' notes, Patty and Yasmine had acted on Eslin's students' notes and offered their evaluation of Eslin's intentions. They expressed concern about students not having had enough practice using the KF. The co-creation of a shared object arose as Eslin negotiated a fit between her ideas and that of the senior teachers by openly discussing how the posts of her students could be used for the next lesson. The resources of students' posting drew Patty and Yasmine to share their teaching experience which helped sustained knowledge advancement, a key element of doing knowledge building, as the shared object of their PLC community.

The two examples in this study illustrate how knowledge building was sustained over the PLC meetings. Specifically, by objectifying the work of the teachers through activity theory, the vignettes in this chapter demonstrate how knowledge building was sustained over time during the PLC and into the classrooms as an outcome of the shared objects created during PLCs. The outcomes of shared objects include innovation as seen from the way thematic writing tasks were implemented as action research as well as permanent advancement of ideas as evident from instructional designs for the science topic of systems. Critically, through a close analysis of teachers' conversations during PLC, activity theory has the potential to make salient how these teachers engaged in the trajectory of knowledge building through shaping and reshaping the object of designing knowledge building lessons for students.

One implication of this work is further work on how to anchor collaborative reflective practices as shared collective objects during PLC meetings. When this is done, it can possibly extend taken for granted weekly meetings from the simple task of working out classroom logistics to professional learning sessions at the teaching workplace.

5.7 Conclusion

CHAT provides the grounds for conceptualizing the work of teachers in professional learning communities. While there is further analysis to be undertaken and the limited nature of the examples represented is acknowledged, we contend that this current analysis from a CHAT perspective enriches our understanding of how knowledge building principles are negotiated into teaching plans during PLC meetings for classroom implementation. By observing how teachers move in and between different activity systems, we are able to conceptually locate them in social landscapes where curriculum, use of technology, activities of lesson planning are regulated by resources. These resources are both material (online knowledge building forum, diagrams, assessment rubrics, students' posting, building terrariums) and conceptual (structured writing process, diagrammatic linear writing process, scientific knowledge, pedagogical knowledge). Through negotiating individual objects for creating shared objects, and managing tensions arising from co-creation for making professional decisions, the case examples illustrated how negotiating shared objects could support professional learning and action at the education workspace.

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Part III
Technology and Education

Chapter 6
Applying Just Manageable Differences as a Guiding Principle for Course Transformations

Kevin Hartman, Jaime Koh, Nathalie F. Goodkin, and Dini Dzulaikha Binte Dzulkifli

Abstract This chapter chronicles the 3-year journey of refining a multidisciplinary science course focused on solutions to environmental sustainability issues. During this time, we developed and applied the principle of *just manageable differences* to the transformation of the course. Our dual goals were to make the changes from one running of the course to the next such that they tested the ability of the teaching team to orchestrate the learning activities and continuously made the activities more meaningful for students. During the transformation, the design for learning moved from a heavy focus on lecture material and instructor-initiated assignments to more of an ongoing conversation about local sustainability issues and the nature of expertise in the sciences. Changes to the course were introduced during the first lecture session with justifications for each change. Student feedback surveys and course performance metrics were used to evaluate how well the changes were accepted and how meaningful they were with respect to learning.

Keywords Learning design · Orchestration of learning · Course transformation

6.1 Introduction

For university courses, the past is truly a prologue to the present. Nearly every university course comes with its own unique history. Sometimes that history manifests itself as an attempt to recreate a prior semester with the same lectures, slides, and class activities. Sometimes an instructor will even reuse past jokes to fish for the same laughs from a new class. Sometimes a course's history is chronicled in the form of a series of semester exams students use to gain insight into the relative weighting of

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the course's conceptual elements. Other times that history is conveyed through the stories past students tell new students. Even the first offering of a new course may come with historical baggage in tow when its introduction reflects changes in degree programs or the university's priorities.

A course's history has a significant influence on its future when it comes to the constraints for altering its instruction, activities, and assessments between cohorts. Thus, a teaching team cannot ignore a course's history and transform it into something unrecognizable to students and administrators without encountering resistance. Knowing how to navigate the currents of a course's history when introducing innovations to its design requires a diverse set of skills and some guiding principles.

6.1.1 Just Manageable Differences

In this chapter, we detail the process we used to transform a large undergraduate lecture course by using *just manageable differences* (JMD) as a guiding principle. We define JMD as the notion that changes to a course from one iteration to the next can make the orchestration of learning more or less effortful and meaningful. Teaching teams, similar to conductors of an orchestra, are responsible for initially arranging the components of their course into a coherent form, adjusting the pace and sequencing of the learning activities, monitoring student progress and providing feedback to students (Dillenbourg, 2013). In many courses, the *teaching team* may be only composed of an individual instructor who is responsible for every aspect of the course. However, in a growing number of university courses, the teaching team may include several instructors, teaching assistants, university learning designers, and instructional technologists. Some teaching teams even include outside content developers contracted to generate tailormade material and activities. The changes made to a course between one cohort and the next and how the alterations come together in the form of a course's learning activities can impact how difficult each orchestration role is to execute and how meaningful the result of that orchestration is. Figure 6.1 shows how the set of learning activities we used with our course could be plotted in a two-dimensional space incorporating manageability from a teaching team and learner's perspective. When thinking about the space, we used a *normal* class that uses lectures and MCQ exams as the baseline for a low level of manageability difficulty. The greater the deviation away from this standard is associated with a greater manageability challenge for the teaching team and learners.

As an initial example, imagine an open-ended class activity in which the teaching team asks students to choose their own topics for an inquiry-based learning activity. Inquiry-based learning activities challenge students to find their own path through a problem space in search of a solution (Bransford, Brown & Cocking, 1999). Inquiry-based learning activities can come with a high level of ambiguity that students need to be prepared to deal with on their own or a guide who can help them learn to accommodate it (Hmelo-Silver, Duncan & Chinn, 2007). In our hypothetical example, the introduction to the inquiry-based learning activity leaves many students confused

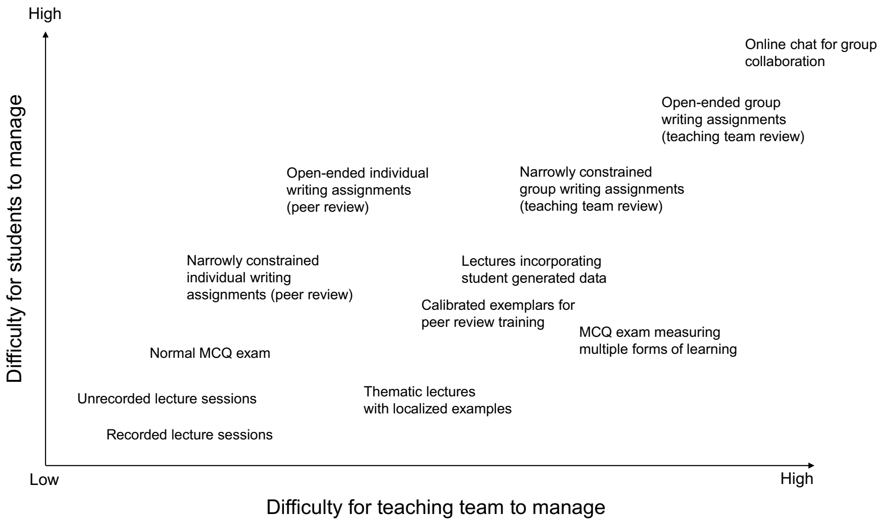

Fig. 6.1 Examples of JMD for students and teaching teams

about its nature and the teaching team's goals. The students have never been given so much freedom. As a result, students find the activity difficult and frustrating because of the concept of the activity itself rather than the concepts found in the course material. At the end of the activity, the teaching team receives a range of submissions, some of which align with the activity's intended learning outcomes. However, many of the submissions appear to go astray from the intended learning outcomes. The teaching team, upon reflecting on the activity, attributes this disconnect between the activity's intentions and the reality of the outcomes to the lack of a model solution. The teaching team revises the introduction to the activity for the following semester's class and shows a few model solutions to help guide students toward the intended learning outcomes. In this case, the difference between semesters makes orchestrating the activity more manageable for the teaching team and less frustrating for the students to complete.

One can imagine JMD working in the opposite direction as well. A teaching team could have introduced the version of the activity with the model solution in the previous semester and observed how a sizeable number of students submitted solutions so similar that they could have fallen from the same answer tree. In that case, the model solutions would have undercut the intended learning outcomes of the inquiry-based learning activity. Changing the activity to require more effort from the teaching team to orchestrate the activity in a way as to guide the class toward a diversity of solutions would make the activity more demanding of the teaching team but ultimately more meaningful for students. Balancing the orchestration of a course's learning activities around what the students and teaching team are capable of is where the awareness of "just" comes in. In pursuing continual course improvement, we contend that learning activities should be challenging, but not impossible, for students to complete. Learning activities should also be challenging, but not overwhelming, for teaching teams to successfully orchestrate. For one of us, transforming a course through JMD means, “Every class session is designed to take me to the edge of my comfort level like I am walking a tight rope for three hours.” In short, designing for JMD puts teaching teams in a similar situation as their students—possibly prepared for the journey and uncomfortably uncertain about its outcome.

In the remaining sections, we describe our experience transforming a large undergraduate science course in accordance with JMD. We begin by briefly summarizing the national context that underlies Singapore’s pursuit of sustainable solutions to its economic and social issues. We then explain the nature of multidisciplinary solutions at a general level. Afterward, we detail how we designed, orchestrated, and measured the outcomes of the differences we introduced during each iteration of the course. We conclude with a few reflections about the transformation journey and future possibilities.

6.1.2 Prologue

The course in question, *Multidisciplinary Solutions to Sustainability Issues*, was introduced to all physics, math, and science programs in response to Singapore’s pressing sustainability challenges and in service to the University’s own Peak of Excellence.

From an international view, Singapore is the technocratic canary in the climate change and sustainability coal mine. It should be noted that the two collections of problems, climate change and sustainability, are interrelated, but fundamentally distinct. Climate change is the near-universal acknowledgement by scientists that the natural environments we find ourselves in are changing at a pace never witnessed by humans and the changes are due to the impacts of our own activities (Houghton et al., 1996). Sustainability is a focus on the resources those human activities produce, consume, and dispose of with the goal being to balance resource use by human activities with the natural processes that generate the resources such that future generations will have access to the same resources that today’s generation does (Kates et al., 2001).

In a world projected to reach 11.2 billion people by 2100 (United Nations, Department of Economic and Social Affairs, Population Division, 2017), Singapore’s 5.5 million inhabitants serve as an interesting case study in climate and sustainability adaptation. As many a Singaporean undergraduate can compellingly communicate, “Singapore is a small country with no national resources other than its people.” An island nation located barely north of the equator, Singapore imports about 60% of its water (Irvine, Chua & Eikass, 2014), more than 90% of its food (Zulkifli, 2019), and all of its fossil fuels (Research and Statistics Unit, Energy Market Authority, 2018). It is an urbanized country with a highly educated, multilingual, and multicultural workforce. Singapore is known for its ability to develop and execute national plans that span generations. For instance, its national water plan was developed in the 1960s in anticipation of future technological advances (Tortajada, Joshi & Biswas, 2013). Singapore has such a prodigious penchant for reclaiming land from the sea that it is almost 25% larger today than it was at its founding (Subramanian, 2017). Nevertheless, Singapore is a small country in a world increasingly defined by outsized global issues.

In a changing world, each of the previously mentioned details carries more meaning than it did a generation or two ago. The public view within Singapore is that when it comes to climate change and sustainability issues a multilateral approach to climate change prevention and mitigation policies is preferable to a unilateral approach (National Climate Change Secretariat, 2012). While those agreements are being determined through international bodies, Singapore can still prepare itself in advance for the adaptation needed to face the changes, just as it has done in the past (Ministry of the Environment and Water Resources, 2016). If Singapore can resolve its own sustainability issues, perhaps it could be the example other cities and nations could rally around when attempting to do the same.

That need for preparation resonated with the University. University leaders instituted a new requirement mandating that all undergraduate students would complete their degrees with some form of sustainability education. How that education requirement was to be delivered was left to the individual faculties. Multidisciplinary Solutions to Sustainability Issues, was the Faculty of Science's approach to ensure all incoming and continuing students in math and science programs met the new requirement.

6.1.3 Multidisciplinary Solutions

To understand the difficulty orchestrating a course focusing on multidisciplinary solutions to complex scientific and social issues, one first needs to understand how multidisciplinary problem-solving works. At first glance, multidisciplinary problem-solving appears deceivingly simple—identify a problem, assemble a diverse team of experts, get the experts to share their understanding with each other, and an innovative solution will emerge. Multidisciplinary solutions include input from experts with different areas of expertise (Remington-Doucette, Hiller Connell, Armstrong & Musgrove, 2013). In urban planning around fragile ecosystems, a multidisciplinary solution might consist of input from a civil engineer, traffic manager, ecologist, hydrologist, geologist, and civil servant working independently on different angles of the same problem. Each individual has a depth of knowledge that can inform the solution to the problem, but none of the experts occupy multiple roles. When experts extend their expertise to multiple fields they are said to be interdisciplinary. The fields may be closely related like hydrology and oceanography or they might be more distant like hydrology and anthropology.

6.1.4 The Classroom Context

With respect to undergraduate courses, the difficulties associated with multidisciplinary problem-solving are thought to be magnified by the nature of the students themselves (Sharma, Steward, Ong & Miguez, 2017). Rather than being experts in their fields with years of experience to draw on, university undergraduates occupy a transitional period between years of general and foundational studies and years of field-specific endeavors.

In the case of our course, this lack of expertise was further complicated by mandating the course for all students enrolled in math or science programs. Not only were the students still learning what expertise in their field looked like, but they were also developing expertise in different fields from each other. With a lecture auditorium filled with students from different majors, the teaching team had to be cognizant that the lecture material could be understood by all of the students and the exams and assignments did not systematically preference students from one major over another. Unlike a course serving as a core requirement, the instructor could not assume that a required course for one academic program was similarly required for each of the other academic programs. In fact, it would be unfair to students, and against the spirit of the course, if the material, assignments, and exams presupposed domain-specific knowledge.

Of similar importance to the multidisciplinary nature of the course content and student body, was how the course was sequenced inside the various academic programs. In short, the course was bolted onto rather than integrated into the academic programs. With a semester's notice, every student in a math, science, or physics program was notified that completing the course was required to graduate. For students entering their final year, this new requirement disrupted their carefully planned academic schedules. It also meant that more than 500 students would suddenly need to complete a brand-new course to fulfil their graduation obligations. Any delays by the University in offering the course or students completing it would mean a 1-year delay in their graduation.

6.2 Year 1: A Translated Replication

To accelerate the development of the course and meet its own ambitious timeline, the University's College of Science recruited a climate scientist who had taught an innovative sustainability education course developed and localized at another university. The thought was that if the course worked well for another national university in the region, it should work similarly well at the University without much modification. Year 1 was designed as a test to see whether the same course instructor, materials, and assignments could replicate the results seen at the originating university.

The idea of taking existing knowledge and porting it over to a new context is known as translation (Liyanage, Elhag, Ballal & Li, 2009). The rationale behind the translation is that smaller or newer organizations can build off the efforts of groups with more resources to solve similar problems.

Translation is not the same as scientific progress. Scientific progress uses the work of others to develop further understanding and new findings. Translation focuses on solving a practical problem by using the processes or methods others used when they attempted to solve the problem. A simple way to think about translation is if a team adequately documents a solution to a problem in one language, then speakers of a different language only need to translate the documentation to make the solution available in their language.

In sustainability research, translation sometimes leads to ecological disasters such as Bali's Green Revolution where developers upended millennia of balancing the island's agricultural needs with its natural resource renewal rates by artificially irrigating the rice fields and imposing multiple harvests a year in accordance with best practices from industrialized nations (Lansing, 2006). In Bali's case, solving the apparent agricultural inefficiencies in the short term disrupted the long-term sustainability of the rice fields to the point where the fields eventually produced lower yields after the Green Revolution took hold than they had in the years leading up to it (Lansing, 1991).

6.2.1 Design for Learning

The first version of the course was designed, implemented, and managed by the instructor and a brand-new team of teaching assistants. The instructor adapted her slides and prepared the course's origin story for the 570 third- and fourth-year students who had recently been informed they needed it to graduate. She approached the course in much the same way she had approached it the year before at her former university. She introduced the course with the following description in the course syllabus and course bulletin:

> The goal of this course is to provide you with an inter-disciplinary introduction to environmental science with key questions to highlight the interconnections between biological, geological, and chemical processes. We aim to convey the basic science behind environmental interactions and place it within the context of human impacts and dependence on the natural world. Understanding how humans interact with the system manage and sustain it within the context of our economies, governments and individual choices will be critical for future thought on environmental science. We will evaluate the problems of environmental science by examining critical issues impacting the health of our population.

Additionally, the instructor used the same assessments, prescribed the same workload, and kept to the same style of communicating with students.

6.2.2 Orchestration of Learning

With the course prepared, one of the University's 700-seat auditoriums booked, and more than 350 students in attendance, the instructor delivered the first of her weekly 3-hour lectures. She began by laying out her high expectations for the course and how she planned on orchestrating its learning. She explained that she would ask questions of the class multiple times each lesson. There would be two midterms and a final exam along with weekly assignment submissions. The exam papers would cover lecture material and details from the assigned textbook chapters and supplementary readings. She highlighted the importance of writing clearly and precisely, especially about complex issues. To make sure students had a chance to demonstrate clear and precise writing about complex issues, she spread three short writing assignments across the semester. So far, the workload looked somewhat high for a mandatory elective course, but not too different from many other science courses.

Then, the instructor informed the class that she would be employing peer review to manage having the three writing assignments with a large number of students. She explained that with peer review, every student would receive valuable feedback much faster from their peers than if the teaching team reviewed each of the 1710 potential submissions. After opening the floor to questions and not receiving any, the instructor commenced with her first package of content.

Nine lectures, three writing assignments, two midterms, and a final exam later, the instructor had delivered a new baseline for what students would expect from her course. The next cohort would arrive in the auditorium a year later after hearing the echoes of the pioneering class.

6.2.3 Outcomes

When the instructor received the results of the student feedback on teaching survey (SFTS) for her course, she read through the open-ended comments as a scientist reads through field observations. Field observations serve as a way for scientists to communicate details about the world to each other. While striving to be as accurate as possible, field observations leave room for thoughts and opinions much like SFTSs do. The instructor reviewed the feedback entries with charity. Every entry communicated a student's experience of the course. Each detail was valuable by itself, but just as multiple field observations add more depth and understanding about a research site, how the details from different entries naturally joined together to tell a richer story was more important than any single detail (Canfield, 2011). After reviewing all of the feedback entries, the instructor reconstructed the timeline of events for her course like she did with her growing collection of coral fossils (Ramos, Goodkin, Siringan & Hughen, 2017).

The story, as told by the student survey results and data she collected during her lessons unfolded as follows. Her first lesson was the high point of the course. It had the highest attendance and highest participation. By the second week, students were deciding for themselves that attendance was optional, that downloading copies of the lecture slides with a fixed page layout and sizing did not suit them, and that they did not like the prospect of their peers having any influence over their academic performance. After the first midterm, the class found that the multiple-choice questions (MCQs) on the exams were difficult to prepare for because the questions were nearly impossible to anticipate and did not align with the "*teaching about*" approach taken in the lectures. Each peer review opportunity was seen by some students as a way for their peers to sabotage the grades of higher performing students. On the whole, the transplanted course looked to be suffering from a dramatic case of student rejection.

Of course, not every statement in the SFTS was negative. Some students praised the instructor's effort, her ability to communicate science, and her passion for making a difference. However, the positive comments were often of a different quality than the negative ones. The positive comments did not leave the instructor with a better understanding of which elements of the course to keep, while the negative comments left no doubt about the elements students would like eliminated. In short, the negative comments were what Siemens and Long (2011) term "actionable" while the positive comments were merely affirming. The instructor kept a record of everything the students mentioned, coded them for emergent themes, tallied the results, and then thought about how to proceed.

6.3 Year 2: A Change in Course Design Philosophy

In response to the feedback to Year 1, the instructor rethought her approach to the course's design and the rationale underlying the learning activities she asked students to engage in.

6.3.1 Design for Learning

The original iteration of the course squarely focused on teaching about multidisciplinary solutions to sustainability issues. It introduced students to a lot of interesting facts and relationships from the fields of physics, biology, chemistry, geology, hydrology, and climatology. What it lacked was a set of stories that tied the facts and relationships together, a larger, overarching narrative that tied each of the course topics together and a set of measures that students could use to make sense of the content and their learning. During Year 2, the philosophy underlying the learning design shifted from *teaching about* to *scaffolding how*.

6.3.1.1 Teaching About

When preparing a course on multidisciplinary solutions, the initial route might be to sidestep the expertise issue and use the course as an opportunity to *teach about* multidisciplinary solutions. *Teaching about* gives students exposure to the features of the problem and how the features can be addressed by leveraging multiple fields. *Teaching about* provides information to students that teaching teams' hope will be activated when the time comes. *Teaching about* keeps the course easily manageable because it aligns with common expectations of a lecture course.

6.3.1.2 Scaffolding How

A more ambitious approach than *teaching about* is to *scaffold how* to engage in multidisciplinary problem-solving by modeling the processes multidisciplinary teams use to develop solutions and give students practice and feedback on the application of those processes. *Scaffolding how* acknowledges that students may not currently have the background knowledge and experience to tackle complex problems at an expert level, but they could still benefit from familiarizing themselves with the process and issues that arise from addressing those problems. *Scaffolding how* changes the construction of the learning activities, their intended outcomes, and the teaching team's orchestration of learning when compared to *teaching about*. To make the transition, the instructor put together a multidisciplinary team.

6.3.1.3 Assembling a Multidisciplinary Learning Design Team

One of the benefits of teaching a particular course only once a year is that after it concludes, the instructor has 6 months to prepare for its next iteration. One of the downsides of teaching a particular course only once a year is that after it concludes, the instructor has 6 months to ruminate on the previous iteration before trying again. Knowing that she was an expert in climate science and an experienced instructor, the instructor could have ignored her collected data and decided to manage her course the same way and hope for different results. However, by doing so she would have submitted to the same impulses that reject scientific consensus to embrace ungrounded theories (McCright & Dunlap, 2011). Instead of falling into denialism, the instructor recruited an educational technologist and learning designer to help her adjust her course before its next start date.

Until now, we have not mentioned the technology used during Year 1 even though this book is ostensibly about using technology to transform learning at the University. This has been deliberate. The reasons the course went awry in Year 1 were not due to the presence or absence of technology in the auditorium. A course design delivered with basic overhead transparencies, paper submissions, and a show of hands for the in-class questions would have likely performed as well as one backed by glossy lecture slides, a custom Learning Management System (LMS) for turning in submissions, and an in-class clicker response system. The origins of the issues ran deeper than not matching the technology to the course design. The issues were inherent in the course design itself and magnified by the campus context. That being said, the course did use each of the aforementioned technologies during Year 1.

By assembling a multidisciplinary team, the instructor gained access to what she was missing—experience with the course designs of many courses. The educational technologist and learning designer were embarking on an ambitious program to harness technology to transform undergraduate learning across the university. Every course on campus was a candidate for such a transformation. The educational technologist and learning designer had seen hundreds of course designs and had access to the technology plans of thousands of courses. They provided the depth of knowledge about learning and a breadth of example cases that no instructor could match.

6.3.1.4 Adjusting Lecture Materials and the Terms of Activity Engagement

Before they reviewed her materials, the educational technologist and learning designer asked the instructor about which elements she wished to maintain and which content she wanted to keep. They acknowledged that they only had enough time to review the lecture slides, provide some suggestions about layout, pacing, and technology use, but once the semester started they knew they would be assisting dozens of other instructors with their own course transformations. Their ephemeral presence created an interesting dynamic. Instead of working to become a high-performance team with a common goal (Katzenbach & Smith, 2015), the technologist and learning designer saw themselves as consultants providing a service to improve the course. Once that service was delivered, the instructor would be mostly on her own—albeit hopefully with a more manageable set of learning activities than she had in Year 1. Institutionally, the educational technologist and learning designer operated by a set of rules in which course instructors made all of the major decisions and their own efforts were calibrated to support those decisions (Tan et al., 2018). They may have questioned the amount of content and how it was presented, but they would never question the content itself. That was the role of the instructor as a domain expert. They may question the framing of an activity or its use of technology, but they would not question the activity itself. That was the role of the instructor as a facilitator.

Despite their transitory participation, the advice of the educational technologist and learning designer was well grounded. They called attention to the way the first lecture framed the semester's course activities and what was left for students to interpret on their own. The original slides explained what students were going to do, but not why they were going to do it other than grades were involved. The framing violated the norms associated with constructive alignment, a set of learning principles making its way through other universities in the region (Biggs, 2014). With constructive alignment, a course designer begins with what students should be able to demonstrate after taking the course (Biggs, 1996). Then, working backwards from these outcomes, the measures that would indicate those outcomes are defined. With the measures identified, the actual assessment activities are developed. Only after the assessments are known does the course designer develop the content necessary for completing the activities.

The educational technologist and learning designer introduced the instructor to the principle of constructive alignment. From there, the instructor laid down the first rule of JMD—transparency of differences:: Every element of the course and every change to those elements would be explained to the students. After modifying her opening lecture to explain how the Year 2 iteration of the course built off the feedback she received about the Year 1 version, adding in more clicker response opportunities, and explaining why peer evaluation is important in science, she again entered one of the university's premiere auditoriums to conduct her first lesson—this time with 540 students.

6.3.1.5 Transforming Activity and Assessment Design

During the first 3-hour lecture of Year 2, the instructor explained her rationale for deciding how to apply JMD. She communicated each of the rationale's elements to the class in common, everyday language. Table 6.1 provides a more academic version of the rationale and how it was integrated into the course.

Multidisciplinary Solutions to Sustainability Issues was the largest course on campus that still engaged students in small group discussion activities without resorting to scheduling additional tutorial sections. This constraint meant that every class activity had to be managed within the auditorium space. After hearing the terms of engagement, the class predictably demonstrated the tragedy of the commons (Hardin, 1968) on several occasions during the in-class activities.

The constraints and ambitions of the course attracted the interest of a learning research team. Members of the team attended the lectures during Year 2. They reviewed the lectures from Year 1. They participated in the small group discussion activities during class and came to the instructor's office hours each week. They got to know the teaching team. They asked a lot of questions about Year 1. Finally, they asked to see the assessments from Year 1—the writing assignments, midterm exams, and final exam that comprised nearly all of a student's final grade.

After looking at the exams, they asked the instructor how the assessments measured the outcomes the instructor wanted students to demonstrate. The answer laid the foundation of the next 3 years, "How would we go about doing that?" The question was filled with openness and a general curiosity about assessment design that formed the foundation on which to build a true collaboration. It was at this point that we started working toward becoming an interdisciplinary team rather than as individuals with complimentary sets of expertise. Our language will mirror this new development from hereon.

If we had followed the best practices of constructive alignment, we would have changed the assessments of learning and then rebuilt the course material such that it aligned to the new learning outcomes (Biggs, 1996). However, by the time of our assessment review, 40% of the semester had already passed. The challenge became

Table 6.1 Rationale informing just manageable differences and methods of implementation

Rationale	Method of implementation
Transparency of differences	Every change from the previous version of the course would be explained during the first lecture
Constructive alignment of learning activities	Every changed activity would be evaluated on how well it met its intended outcomes. Exams would be more balanced between recalling facts and demonstrating competencies
Responsiveness to student needs	While course topics were fixed, the presentation of those topics could be adjusted based on class interest or the teaching team's needs. Every email to the course address would be responded to by a member of the teaching team within the next working day. Issues raised by students in the SFTS and the dedicated course email would be acknowledged and addressed during the next iteration of the course
Positioning peer review as a process for progress	The process for the peer review of written work could be refined but peer review was too central to the understanding of sustainability science to abandon completely
Promoting interaction between students	Opportunities to make lectures and small group activities more interactive would be trialed
Measuring student acceptance and learning	The student data collected during the semester would be analyzed to measure how well the teaching team orchestrated the learning activities and how well students managed them

altering the midterm exam such that it managed to measure the course outcomes more systematically than the previous versions without the differences breaking any of the promises the instructor had made during the first lecture. The midterm covered five lectures and the instructor had committed to filling it entirely with MCQs. After analyzing the midterm from Year 1, we created a rough coding scheme based on Krathwol's revision of Bloom's taxonomy (Krathwohl, 2002). The coding scheme is shown in Fig. 6.2.

Instead of the traditional seven levels of outcomes, our abbreviated scheme collapsed Remembering and Understanding into Recall. Analyzing, Evaluating, and Creating were consolidated into Transfer. Applying was relabeled as Application. Essentially, items that could be answered by remembering the facts mentioned in the lectures or readings fell into the Recall category. Any item that the instructor demonstrated how to solve in class fell into the Application category. Any item that students should have been prepared to solve given what was discussed in the lecture but students had never been explicitly shown how to solve was labeled as a Transfer

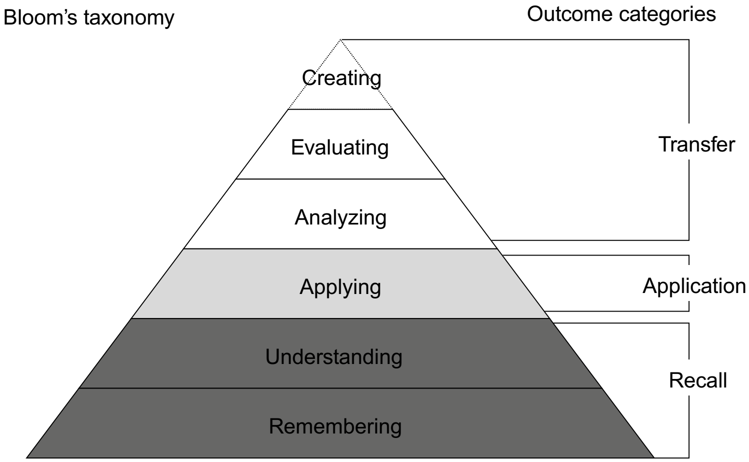

Fig. 6.2 The coding scheme for learning outcomes of exam items

item. The clear definitions of the three categories made it possible to code the previous exams. Upon analyzing the first midterm from Year 1, we observed that the prior year's exam was composed of 60% Recall items, 12% Application items, and 28% Transfer items. This finding aligned with the student feedback that surfaced exam items that tested the memory of facts from the readings, and violated the idea that the course heavily valued critical reasoning and analysis.

To correct the imbalance, we drafted a new midterm that apportioned 40% of the items for Recall, 20% for Application, and 40% for Transfer. While updating the midterm to fit the new constraints, we streamlined the design of the items such that they all had the same number of responses with the wording of similar technical language and word length. To make sure the items were fair, even if we knew some of them were difficult, we trailed several drafts of the items with the teaching team. Any item that was correctly answered by the majority of the teaching team remained in the midterm. Any item that did not reach that threshold was reworked or replaced. The process of generating a balanced set of items and piloting multiple versions of items with the teaching team ahead of the exam's printing deadline was just manageable.

In accordance with telegraphing all the differences and the reasons behind them, a week before the midterm, we sent an email to every student that explained the composition of the midterm and the rationale behind its design. We wrapped the explanation in a genuine and supportive message. The message also indicated that 40% of the exam included items that required students to go beyond what was mentioned in class.

Exit interviews with students on exam-day gave the impression that the new midterm was difficult, but just manageable and fair. The automated exam scoring system indicated the same. When we presented the distribution of midterm scores later in the semester, the class gave a collective gasp. While the distribution was not noticeably different from the past year, it did indicate that the midterm was not built for some percentage of the students to exhibit very high scores. Instead, it was designed to help us understand where the gaps in reasoning were and give students room to surprise us. As we did not receive a wave of emails complaining about the nature of the midterm, we concluded that the exam was just manageable for both the teaching team and the students and kept the design of the exam and the item generation process the same for the second midterm.

6.3.2 Orchestration of Learning

Following the relatively positive success of the midterm exam changes, we sought to restructure the focus and delivery of the remaining lectures and fine-tune the peer review process.

6.3.2.1 Transforming the Orchestration of Lectures

After establishing the rules for generating well-crafted and balanced midterm items, we moved our transformation efforts to the next most obvious issue—the inverse relationship between student attendance and the week of the semester. Each week, fewer students attended the lecture than the week before. We could see it in the unfilled seats in the auditorium and the dwindling participation rates for the clicker questions.

From talking to students, we knew and could empathize with the reasons. As a semester progresses, students are under more obligations from more sources and they rebalance their time accordingly. Some instructors rationalize the decline as a character flaw common in students. Other instructors actively fight against the trend by mandating attendance or incorporating weekly quizzes that require students to show up each week. By making structural changes, these instructors can continue delivering lectures to a roomful of students. However, tactics that incentivize students to appear in class make it difficult to make claims about self-directed learners and intrinsic motivation.

From the front of the class, there is a difference between teaching a half-filled seminar and a half-filled auditorium. In the seminar case, the instructor can strategically place students around the discussion table to create a sense of intimacy. Working with a half-filled, or quarter-filled auditorium is different. Students predictably disperse themselves in small clusters throughout the auditorium. Those clusters are then difficult to consolidate into one region of the auditorium. For the second part of the semester, we worked under the hypothesis that if we transformed the lectures into sequences of interestingly packaged content interspersed with engaging discussion questions, we could at least stem the drop-off in attendance between each week's lecture.

In Year 1, the pace of a week's lecture followed a predictable pattern. The instructor would spend 5–10 min on a topic and ask a clicker question that measured the students' comprehension of what was just explained. During the final 15–20 min of the lecture period, the instructor would release a set of small group discussion questions. Students would assemble into groups and discuss among themselves or the teaching team. As the weeks went on, the time between the clicker questions increased and the participation at the end of class discussion questions decreased.

As we discussed how to transform the orchestration of the lectures, we realized that we had two different notions of what was important for delivering a "good" lecture. From a domain expert's standpoint, introducing students to facts and definitions that they can later apply was essential to a good lecture. From a preparation for future learning standpoint, introducing students to activities designed to help them reason through complex issues in the future was the most important element (Bransford and Schwartz, 1999). Because we were operating from different starting points, as many multidisciplinary teams do, the ease with which we transformed the midterm items did not translate to reworking the lecture content. As such, we decided to start small by working on the details we could agree on. We saw updating the data displayed in the slides to the current year and localizing the examples to Singapore instead of one of its nearby neighbors as must-haves. We also agreed to incorporate more student-generated data into the lectures by devoting time to charts of their open-ended responses to the weekly homework assignments. As we worked on the updates and coding student data on a weekly basis, we kept talking about what were the most important stories to convey to students from a multidisciplinary perspective.

Through those discussions, we started converging on what made the Singaporean context special when it came to the four remaining sustainability issues: land, water, waste, and climate. Beginning with the topic of land use, we presented the lecture as a way to explore the options a country has for using a resource or dealing with an issue. We reframed the entire lecture to put students in the role of land managers who had to decide how Singapore's and the world's land resources should be allocated. At the beginning of the lecture, we asked students how to prioritize the world's land use by answering a clicker question without an objectively correct answer. As the lecture unfolded, we showed the class how much of the world was dedicated to each use and how the local context did not match the world context or the *optimal* context. Then we asked students to prioritize the world's land use again with a similar clicker question. Each time the class prioritized the options, we would introduce a little more information that presented a different discipline's perspective and linked it to another option. Periodically returning to a central question with a bit more information and highlighting how the class's opinions shifted became the recurring theme for each of the course's lectures.

For each of the options for the central question running through the lecture on land use, we asked students additional clicker questions that indicated how they would personally like to live versus the rest of the world. Then in small groups, students talked about their priorities and we had students revote. For instance, we asked students how close they would like to live to their neighbors in a residential area based on the land usage of Australia, the United States, Europe, Los Angeles, Singapore, and Mumbai. Not surprisingly, students from a country that works to fit 7,600 people/km would have liked more space between people. Most students picked the United States. Then we showed the class everyone's answers and the implications of those answers by displaying what percentage of the Earth would be needed if everyone lived like each of the six options. As far as population density is concerned, living like the average American would require the land area of 1 and 1/3 Earths. Living as Singaporeans do would use about as much land as Singapore, Malaysia, and the island of Borneo combined.

At the end of each lecture→question→discussion→question cycle, we crystalized the discussion by pointing out how changes in the resulting distributions were indicative of multidisciplinary solutions and how each new option was equivalent to adding a new expert to a solution team. We further localized the lectures to the Singaporean context by using Singapore as the basis of measurement as much as possible. For instance, most students understood how large 700 km^2 was. It was the size of Singapore. However, students did not have a way of quickly estimating exceedingly large areas, so we used the size of Singapore as our standard measurement of area. This meant that the world's available land area was the equivalent of roughly 211,000 Singapores[1] (Sharp, 2017). In maps, we overlaid an appropriately scaled image of Singapore to show the vastness of the Amazon Rainforest Basin (8,570 Singapores[2] and shrinking (Kauppinen et al., 2014)), and the American Dust Bowl in the 1930s (571 Singapores[3] and mobile (Worster, 2004)).

6.3.2.2 Re-orchestrating Peer Review

If the students of Year 1 had collaborated with each other to design courses, all peer review activities would have been removed from the curriculum and perhaps the university. Instead of heeding the advice of the past class, the teaching team decided to continue peer review for another cycle. However, some of the students' fears were addressed by adjusting the peer review process to make it just manageable for the students. For Year 2, instead of all essays being peer reviewed, students first worked in groups to write an action plan during the first half of the semester. The action plan related to managing the concentration of Lyme disease present in a forest. The teaching team reviewed the group essay and made its targeted feedback comments available to the teams.

Assigning the team action plan before the individual paper was intended to introduce students to science communication within the safety of a group environment where the teammates could support each other and the individual stakes were lower. Then, all students could incorporate the teaching team's feedback into their writing

[1]510 million km^2 (area of Earth) x 29% (percent of Earth that is land)/700 km^2 (area of Singapore) per Singapore = 211,000 Singapores.

[2]6 million km^2 (area of Amazon Rainforest Basin)/700 km^2 (area of Singapore) per Singapore = 8,570 Singapores.

[3]400 thousand km^2 (area of the American Dust Bowl)/700 km^2 (area of Singapore) per Singapore = 571 Singapores.

for the individual assignment and use the teaching team's comments as models for their own peer reviews.

The individual assignment was due near the end of the semester. Each student wrote an analysis about whether population or consumption was more of an underlying cause of the world's environmental problems. Each individual paper was evaluated by three classmates according to a rubric developed by the teaching team. The teaching team then reviewed each reviewer's comments on the qualities of effective communication. When the final calculations were completed, each peer review counted for less than three-tenths of a percentage point of a student's final grade. In fact, the quality of the feedback comments contributed more to a student's final grade than the peer reviews did.

To emphasize how important peer review is to scientific communication, a sizeable portion of the first lecture was dedicated to explaining the process experts go through when generating knowledge and proposing solutions. In both academic and professional settings, ideas are evaluated by peers. The feedback from such reviews is not always easy to hear and it is not always meaningful, but through practice people can improve how they communicate their ideas and provide critical feedback. During the lecture, the framing of peer review transitioned into the evolving story about the fall of Easter Island as new scientists added new data that forced the rethinking of prior hypotheses to illustrate that even the interpretation of facts should be questioned critically.

Just prior to the opening of the peer review period, students were asked to evaluate three sample action plans based on the Lyme disease topic. The teaching team deliberately wrote the action plans as calibrated exemplars that called attention to differences in the quality of reasoning. Calibrated exemplars can be used as instructional aides that provide students with an awareness of the range of possible solutions and a guide to the quality of those solutions (Heldsinger and Humphry, 2013). Each of the exemplars exhibited good use of the mechanics of writing like proper spelling and correct grammar. The three exemplar action plans differed in the sophistication of their reasoning. The first action plan exhibited obvious factual misconceptions and errors before detailing an unworkable solution. The second action plan heavily relied on lecture material to support the plan detailed in the textbook. The third action plan exceeded what was taught in class and incorporated outside information to generate a novel solution. For each exemplar, students were then asked to estimate where they thought it would fall in the distribution of all submitted action plans. The following week, the instructor used the final minutes of the lecture session to show students the results of their estimates and how they compared to the teaching team's ratings. In aggregate, the class' ratings were not too different from the teaching team's ratings. The instructor used this as evidence that students could rely on their peer reviews in aggregate even though they may not agree with every comment. The results were shared with the class prior to the peer review activity.

6.3.3 Outcomes

The most important outcome from Year 2 was the validation of the JMD rationale by the students. At least one student positively mentioned each of the rationale's elements in the SFTS. Mapping how the differences in Year 2's course followed directly from the experiences of Year 1's students set the stage for a semester of success. The SFTS from Year 2 reflected positively on the differences we introduced. The course received 50% fewer negative comments about the exams and peer review activities. Even though the exams were designed to be more challenging, students indicated that they thought they were fair. A few students went as far as spontaneously mentioning they learned something while taking the exams.

When appraising the lectures, students mentioned the positive change in lecture structure from the first half to the second half of the semester. While it was heartening to know that the changes we made resonated with students, we were keenly aware that the course was still not delivering on helping students to reason through multidisciplinary solutions to Singapore's sustainability issues as well as it could. We used the six months between semesters to address this gap.

6.4 Year 3: Balancing Meaningful and Manageable

Confident in our process for transforming course lectures from the presentation of facts, figures, and definitions into narratives built to challenge the reasoning of students and aligning the exams to better test how students reasoned through new challenges, we officially signaled the course's change in learning design in the course syllabus and online bulletin. Students registering for the course in Year 3 could clearly read:

> In this inter-disciplinary introduction to environmental science, we will look at (1) the interconnections between biological, geological, and chemical processes, (2) how human behavior responds to and shapes these processes, and (3) how interdisciplinary communication, through scientific research, governmental policy, economics, and education, is essential for identifying, managing, and solving for human impacts on the natural world. This course will provide opportunities to learn the basics of environmental science, share insights you have gained from prior coursework with students from other programs, and identify, evaluate and propose solutions to relevant sustainability issues.

The course had always provided opportunities to learn the basics of environmental science. Year 2 provided students with more opportunities to share with others, but it could have delivered better in allowing students to propose solutions to *relevant* sustainability issues and allowing them to experience the challenges associated with science communication. To honor all of the listed learning outcomes, we significantly transformed the core of the written assignments. In doing so, we attempted to make the assignments more meaningful for students and more challenging for the teaching team to orchestrate.

6.4.1 Design for Learning

Once we had all of the lectures converted to the new format, the assessments designed to measure three types of learning outcomes, and the acceptance of students, we felt confident enough to introduce novel learning activities that matched the learning outcomes that were not supported by the midterm items. During Year 3, we introduced open-ended essay topics and an online chat activity that asked students to generate climate action plans for a local and global context in small groups.

Until Year 3, all of the topics for the writing assignments had been designed with a limited scope. Even when the first writing assignment was transformed into a group assignment for Year 2, the topic remained the same. Since the first iteration of the course, students had provided us with nearly 500 action plans related to controlling Lyme disease in a temperate forest. The presence of Lyme disease within an ecosystem is a canonical example of a complex system. Complex systems permeate discussions of climate change and sustainability issues. Lyme disease is also an ailment most students in our course will hopefully never encounter and is present in environments many of students had never seen.

Students had also produced nearly 1000 essays on whether consumption or population pressures were more responsible for the world's environmental problems. The goal of the writing assignments was originally to give the teaching team material to assess how well students used the language of the course—its terms, definitions, and concepts—when describing ecosystem management and climate issues. With the topics set so narrowly, the assignments were straightforward for the teaching team to evaluate. However, the unintended consequence of making the assignment manageable for the teaching team was that we also restricted the possible ways students could surprise us with their insights.

As we applied JMD to evaluate how well our course activities delivered on our intended learning outcomes, we had to answer difficult questions like whether another 125 action plans related to deer, trees, mice, ticks and Lyme disease, and other 600 essays weighing consumption and population demands would tell us anything new about the students, our course design or the teaching teams' capabilities that the previous hundreds of essays had not. Rather than continuing down the well-worn path, we decided to unleash the course's students and their creativity in identifying and proposing improvements to local and national sustainability issues. We introduced the change knowing that the resulting action plans would be more time consuming for the teaching team to evaluate, and it opened up the potential problem of randomly selecting students to peer review a set of three action plans that were quite different from each other.

In our context, local issues related to those issues affecting the University and its surrounding community. National issues pertained to issues affecting Singapore as a whole. We followed the same sequence of introducing the group assignment to prepare students for the individual assignment as we did in Year 2. However, we transformed the rubric to reflect the elements we deemed important to quality science communication: clarity, use of argumentation, explanation of context, incorporation of evidence, and proper sourcing of quality evidence. The same rubric was used to evaluate each of the student writing assignments.

6.4.2 Orchestration of Learning

With all of the lectures in Year 3 organized around a central theme, incorporating student-generated data, and only covering the factual elements necessary to keep students involved with the telling of a coherent sustainability story, we worked to better prepare students for peer reviewing each other's work and engaging in multidisciplinary problem-solving.

6.4.2.1 Repetition of Peer Review

We found in our Year 2 peer review exercise with calibrated exemplars that the majority of students could identify low quality work but had some difficulty distinguishing moderate-quality work from high-quality work. In Year 3, we provided students with more guidance about what features to look for in quality work and gave them more opportunities to evaluate the work of different quality levels. To help scaffold students in evaluating features of quality work, we introduced students to a more comprehensive rubric. We incorporated the application of the rubric into each of the weekly homework assignments and indicated the teaching team would use them on the non-peer review writing assignments.

Prior to each lecture, students would read an article or essay and evaluate it using the rubric. The teaching team would then aggregate the results into a slide which the instructor would walk through in detail with the class during the lecture session. In walking through the features, the instructor showcased her own evaluative reasoning. The regular feedback cycles let students see how well their application of the rubric matched the teaching teams' and let the class know that the class, as a whole, was consistently improving its application of the rubric each week. There were six "practice" peer review cycles prior to the "live" peer review cycle that included the student's writing assignments.

6.4.2.2 Priming Collaborative Multidisciplinary Problem-Solving with Online Chat

After talking with students and analyzing the class survey responses, we discovered that the most popular strategy for completing the group writing assignment was to divide up the labor such that each team member was responsible for their own section of the paper. One student would write the introduction. A second student would write the problem statement. A third student would write about the current solutions. A fourth student would detail the management solution. The final student would write the conclusion. One or two group members would then harmonize the language to make the sections flow together.

In practice, this *divide and conquer* approach meant each team member only had to write one to three paragraphs and could do so independently of the rest of the group members. In Year 3, we added two online chatroom activities to the course. During the activities, students worked together in groups assigned by the teaching team to create a national climate action plan for Singapore and international one. Our goal was to create an assignment that forced students to collaborate with each other rather than merely cooperate with each other. By priming the groups for collaboration, we hoped to observe more of a multidisciplinary approach to the action plans.

We used the Learning Activity Management System (LAMS) to deliver chat activities (Ghiglione & Dalziel, 2007). LAMS allows instructors to sequence different types of learning activities together into a single assignment. In our case, we sequenced a grouping activity together with two chat and scribe activities. The chat and scribe activities allow all of a group's members to make comments to each other in a chat frame. The first member to join the group is assigned the role of the Scribe. The Scribe's job is to compose the group's written submissions. When ready, the Scribe can submit the work. If each of the group members agrees to the submission, the activity is completed. If any of the group members do not agree to the submission, the group returns to the chat frame to help the Scribe make further revisions.

To diversify the groups, we balanced the assignment of students to groups by their major of study so we spread the number of math, science, and physics majors evenly across each of the 122 five-member groups. We created the grouping table through the University Learning Management System (LMS) and forwarded the groupings on to LAMS and the students themselves in the form of a spreadsheet.

The affordances of the LAMS' chatroom environment allowed the teaching team and researchers to analyze the process students used to generate their action plans as well as the plans themselves. Every line of text entered into the group's private chatroom was permanently recorded to the group's chat history. Students who entered the chatroom later were still shown all of the prior chat history so they could catch up with the ongoing conversation.

To orchestrate the activity, the instructor refrained from lecturing during "e-week". "E-week" was a campus-wide initiative to encourage instructors to use online resources to facilitate their learning activities. Without the need to attend a 3-hour lecture, students then had time to engage in the online chat activity. During the 2 weeks that the activities were available to students, a member of the teaching team answered every email sent to the course address within 2 hours. Every response was designed to be positive and supportive of the contacting student and understanding about the issue they described. After all of the action plans had been submitted, the teaching team evaluated them according to the evaluation rubric used throughout the semester.

6.4.3 Outcomes

Unfortunately, the attendance pattern observed in prior semesters continued into Year 3 even with a complete slate of enhanced lectures. Maximum attendance and participation occurred during the first lecture and predictably dropped with each passing week. There was no difference between the attendance rates for Year 3 and those from the previous years.

What did change was the frequency of student responses noting the quality of the lectures. Students participating in the SFT exercise mentioned the strength and organization of the lectures much more often in Year 3 than the previous years. Few students commented on the peer review activity or the composition of the exams.

Allowing students to generate their own topics for the individual and group writing assignments, predictably increased the diversity of the plans. Students introduced dozens of local and national issues that fell nicely into the course themes. The teaching team enthusiastically reviewed the group action plans and focused on providing feedback that aligned to the enhanced rubric. The comments the team left to students served as a model for how to leave critical, yet supportive, feedback to a peer.

The chat activities did indeed require more effort by the teaching team to manage and even greater effort from the students to complete. Through the LAMS chat activities, 590 students generated 244 action plans. On average, each student produced 72.30 (SD = 68.18 entries) chat entries. The teaching team member responsible for student support sent 183 emails to facilitate the activities.

When we piloted the activities, we anticipated each plan would take under an hour to complete. In practice, some groups spent more than two hours to complete a single action plan. In response, the instructor publicly acknowledged the miscalculation and praised students for completing the assignment in less-than-optimal circumstances. The instructor also sent an email to the class with a similar message.

Overall, we asked students to put in more effort and complete more assignments in Year 3 than in Year 1. However, because of our use of JMD to anchor how we presented each new activity and change to the course, students were accepting of the changes and associated workload. What we did not expect was that some students would ask for a channel to communicate their action plans to campus and national decision-makers. The spontaneous requests served as an indicator of the pride students took in their work and the level of civic responsibility that motivated them.

6.5 Conclusion

During our time together, we pieced together the elements of JMD to transform a large lecture course. The constant work-in-progress tested the ability of the teaching team to orchestrate the course's learning activities and the ability of the students to manage a more diverse set of activities. Through the iterative cycles, the course evolved from an international transplant to a thoroughly Singaporean product. While the transformation may have required the sacrificing of some content, the reduction freed the time necessary for scheduling more meaningful activities throughout the semester.

Year over year, students indicated a higher level of appreciation for the structure and nature of the course and for the instructor herself. It is our conclusion that the elements of JMD could be used in any large lecture class where a teaching team is motivated to change the terms of student engagement and learning.

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Chapter 7
Preparing Pre-service Teachers to Integrate Technology into Language Classrooms

Libo Guo, Mary Ellis, and Huaqing Hong

Abstract This chapter explores the question of how teacher educators can prepare student language teachers to teach in digital classrooms. More specifically, it considers the following questions: (1) what makes an effective language teacher in a digital classroom? (2) how can teacher education prepare language teachers to effectively use ICT? We draw on our teaching and research experience in working with student teachers in preparing them to teach the English language in the digital classroom in Singapore. Data sources for this chapter include our course curriculum/syllabus and assessment materials; students' reflections on educational policies on ICT (e.g. Ministry of Education master plans for ICT in education, Ministry of Education, Singapore [MOE], 2018); their reflections on a field trip to an innovative, ICT-saturated learning hub; their analysis and commentaries on selected research literature on ICT integration in schools and their reflections on the use of the Net Gen Learners' Terrace, a new initiative of the National Institute of Education (2017) to support telecollaboration. Our work has developed the following principles. First, student language teachers need some knowledge of language learning and teaching, as a guide for their pedagogical decision-making. Second, they need first-hand experiences of reading and producing digital projects with a range of digital platforms. Third, they need opportunities to observe and reflect on innovative practices through field trips and through reading relevant research literature. Finally, they need sufficient knowledge about the school (local) contexts that may affect ICT integration in the classroom.

Keywords Computer-assisted language learning · Pre-service teacher education · Technology integration

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7.1 Introduction

The past 20 years have seen enormous advancements in digital technology and its wide-spread integration to teaching and learning in K-12 contexts and beyond in many countries. While there is little doubt that quality teachers have been key to quality ICT-enabled classrooms, what teacher educators can do to prepare language teachers to teach in the digital classroom remains little known and has been receiving increasing research attention in the field of computer-assisted language learning (CALL) (e.g. Arnold & Ducate, 2015; Cutrim Schmid, 2017; Kessler, 2013; Hubbard & Levy, 2006).

To contribute to this growing body of research on language teacher preparation in ICT, this chapter considers the following specific questions: (1) what makes an effective language teacher in a digital classroom?; and (2) how can teacher education prepare language teachers to effectively use ICT? It draws on our teaching and research experience in working with student teachers when preparing them to teach the English language in the digital classroom in Singapore. Data sources for this chapter include our course curriculum/syllabus and assessment materials; students' reflections on educational policies on ICT (e.g. Ministry of Education master plans for ICT in education, MOE, 2018); their reflections on a field trip to an innovative, ICT-saturated learning hub and on the use of the Net Gen Learners' Terrace (NGLT), a new learning space at the National Institute of Education, Singapore to support telecollaboration); and their analysis and commentaries on selected research literature on ICT integration in schools.

7.2 Literature Review

We briefly review the literature in three related areas: first, is there a need for CALL teacher education, given that most of our pre-service teachers are in their 20s or 30s, who were born after the mid-1990s, when ICT has proliferated in much of modern societies? Second, if the answer to the first question is positive, then what do student teachers need to know and be able to do in the digital (i.e., computer-assisted) language classroom? That is, what are the competencies that student teachers need to develop in order to function effectively in the classroom? Thirdly, how do teacher educators help them to develop these competencies?

7.2.1 A Need for Teacher Education in CALL

Prensky (2001) argued that because young people have grown up with digital technology, they are more comfortable and proficient with digital technology than their parents and teachers. The implication of Prensky's argument (2001) may be that it is not necessary to include technology in education for younger generations, whom he called "the digital natives." Empirical studies about the technological competencies and expertise of the younger generation, however, have yielded a more nuanced picture than what a dichotomy of "natives" versus "immigrants" might suggest. García-Martín, Merchant, and García-Sánchez (2016), for example, have conducted a survey of 919 new university students and postgraduate students in the UK. They found that "(a)lthough these new entrants to higher education were familiar with a range of new technologies, their experience of using them was mainly restricted to everyday social interaction" and that "such an understanding on its own is unlikely to be sufficient to drive the sort of changes that are required to develop 21st century literacies in the classroom." (p. 51).

Similarly, based on a survey of 55 pre-service teachers in the US, Lei (2009, p. 92) found that "although digital natives as preservice teachers use technology extensively, their use of technology has been mainly focused on and related to their social-communication activities and their learning activities as students. As preservice teachers, they lack the knowledge, skills, and experiences to integrate technology into classrooms to help them teach and to help their students learn."

In the area of CALL, Kessler (2013, p. 1) notes that "teachers are often overwhelmed by the technology that is available to them and feel unprepared to make informed decisions about the selection, creation, and use of a particular technology-based tool or resource. They are also generally uninformed about the potential assistance that technology can provide them with in their language teaching pursuits."

While this review of the studies is clearly limited, we may summarize the key points as follows: pre-service young teachers do use ICT tools extensively but mostly in informal and social settings, and therefore they should develop relevant knowledge and skills in order to integrate ICT in the language classrooms as these subject-specific knowledge and skills are unlikely to grow out of their informal, everyday and personal experiences.

7.2.2 CALL Competencies

Hubbard and Levy (2006) made a distinction between technical knowledge and skills and pedagogical knowledge and skills in characterizing the CALL competencies. Technical knowledge and skills refer to competencies in working with the computer system (e.g., hardware, software and networking) while pedagogical knowledge and skills refer to competencies to "effectively use computer in language teaching" (p. 16). Kessler (2013) proposed a more detailed set of pedagogical skills. He noted that "(e)ssential skills for the teacher range from the ability to evaluate the quality of Internet resources to the creation of each and every aspect of CALL-based instructional activity for specific groups of students." (p. 3) For example, a language teacher may need to be able to locate a movie file from the Internet, evaluate its usefulness for his or her classroom and integrate the file into his or her lesson. At a more advanced level, the teacher may need to create a video "using a combination of personally created images, text, and voice recordings" (p. 4) and integrate the video effectively in his or her lesson.

Drawing on Hubbard and Levy (2006), Cutrim Schmid (2017, p. 25) further identifies 9 CALL competencies: C1—"having a sufficient technical foundation"; C2—"using pedagogical approaches that are intentional and well-considered (e.g. in accordance to current theories of teaching methodology)"; C3—"understanding frameworks for the evaluation of CALL in all its forms"; C4—"making informed judgments on the suitability of the tool for the task"; C5—"appreciating the strengths and limitations of the technological options at hand"; C6—"being able to identify and understand the impact of authentic technological constraints and to work creatively between them"; C7—"capacity for research and development in CALL"; C8—"being able to act to build CALL knowledge in others"; C9—"having a positive attitude toward using electronic technology in their teaching."

In the area of training teachers to telecollaborate with other educators, O'Dowd (2015) developed a comprehensive model of the competences of the telecollaborative language teacher, which includes organizational competencies (e.g., use online networks and his/her own professional contacts to locate possible partner-teachers in distant locations and explain to them his/her plans and expectations related to a possible exchange), pedagogical competencies (e.g., identify tasks for the online exchange which meet at least some of the objectives of the participating classes' curricula, and integrate appropriate assessment procedures and rubrics which accurately reflect the activities which students carried out during their exchange), digital competencies (e.g., choose the appropriate online communication tools to fit both the everyday online practices of the students as well as the project's aims) and attitudes and beliefs (e.g., a belief that culture plays an intrinsic role in foreign language education and online communication).

As we see from these conceptualizations of CALL competencies by leading scholars, language teachers need to develop some key competencies, including firstly, the ability to work in the digital environment, familiarizing themselves with a range of technological tools, both comprehending or consuming the media texts and producing them; secondly, the ability to teach language in the digital environment, making informed pedagogical decisions based on information about their pupils and their learning; and, thirdly, the ability to telecollaborate with their pupils and other educators if necessary (see also TESOL, 2009).

7.2.3 How to Develop CALL Competencies

Researchers have recently emphasized the power of sociocultural approaches to teacher learning, where social and experiential learning are believed to contribute to developing CALL competencies. Meskill, Anthony, Hilliker-VanStrander, Tseng and You (2006, p. 283), for example, note that "effective integration (of technology into everyday teaching and learning) after all is a complex, situated activity. What educators need to know when it comes to effective integration is in large part developed experientially in real institutional contexts." Similarly, Cutrim Schmid (2017, pp. 8–14) has proposed several useful approaches, which include: experiential modelling, research-oriented CALL teacher education, peer-assisted collaborative learning, situated practice and vicarious experiences. "In experiential modelling, trainees experience the tools and processes they are supposed to use in their future practice. It is expected that these experiences will foster gradual learning, leading to deeper and more durable changes in teaching behaviour and attitudes" (p. 11). In research-oriented CALL teacher education, teachers are engaged in critical reflection on their technology use in the classroom. In collaborative peer-assisted learning, teachers are encouraged to collaborate in order to trigger deeper reflection and learning. Situated learning means that "learning knowledge and skills take place best in contexts close to those in which they will be used. For language teacher education, this means the use of technology in authentic language teaching scenarios" (p. 13). Vicarious experiences mean that "in the absence of concrete opportunities for authentic situated practice, trainees can benefit from observation and analysis of contextualized and relevant examples of technology use" (p. 14).

In addition, with regard to CALL curriculum design and pedagogy, Reinders (2009) surveys and discusses different options through which technology can be taught to language teachers, for example, offering a dedicated course on technology or integrating technology into classroom instruction; generic technology education (i.e., focusing on "basic skills that will enable them [language teachers] to apply any technology to a teaching situation", p. 233) or more specific technology education (i.e., "how to use a certain commercial program", p. 233) and so forth. And Kessler (2017) describes his Master's degree course on CALL in a university setting in the U.S., including the context of the course, its aims, course readings, and assessment tasks.

While these efforts are clearly informative and thought-provoking, more work is needed to offer specific guidelines as to what initial CALL competencies a pre-service teacher needs to develop in his or her bachelor's degree programme (i.e., what he or she needs to know and be able to do in order to become a qualified beginning teacher) and what teacher education needs to do in terms of curriculum and pedagogical activities. Hence we aim to investigate the following research questions: (1) what makes an effective language teacher in a digital classroom?; (2) how can teacher education prepare language teachers to effectively use ICT? In what follows, we describe our attempts at identifying the CALL competencies in a pre-service teacher education programme in Singapore and the curriculum and pedagogical activities to develop these competencies in the student teachers.

7.2.4 Background to the Course

Since 1997, Singapore has implemented four major ICT-based education initiatives, known as the Masterplans for information and communication technologies in education. While the third Masterplan (MP3, 2009–2014) focused on fostering student self-directed and collaborative learning through ICT use, the fourth and current Masterplan (MP4, 2015–the present) focuses on quality learning and is aligned to MOE's direction of Student-Centric and Values-Driven education. The vision of MP4 is to nurture "Future-ready and Responsible Digital Learners"; and "[t]he two enablers are: (i.) Teachers as Designers of Learning Experiences and Environments; and (ii.) School Leaders as Culture Builders." (MOE, 2018).

The course that we describe in this chapter is situated in this education policy environment and is titled "Using IT in the language classroom." Since 2011, the first author (Guo) and second author (Ellis) have been offering this course to various groups of Bachelor of Arts/Bachelor of Education student teachers, most of whom are in their 20s or 30s with some in their 40s. Each run of the course consists of 11 weeks, with 3 h of work each week. It seeks to prepare pre-service teachers to teach the English language with the assistance of ICT; in other words, to prepare them to grasp the essential skills and knowledge that would enable them to function effectively in "core practices" (Grossman, Hammerness, & McDonald, 2009) of teaching in a digital classroom, practices that "occur with high frequency in teaching", "preserve the integrity and complexity of teaching" and "are research-based and have the potential to improve student achievement" (p. 277). Based on the research literature (e.g. Hubbard & Levy, 2006) and our analysis of the educational policies in Singapore, we first identified some core practices in the digital classroom (e.g., helping pupils carry out meaningful digital learning activities with relevant ICT tools) and selected topics/knowledge/skills/pedagogical activities that would empower the student teachers to perform well in the core practices in their future classroom. Over the years, we have included the following broad topics in the course:

- Learners' language and literacy practices in the Digital Age;
- The influence of digital cultures on English curricula and pedagogy;
- Conceptions of digital literacy (e.g., media literacy, information literacy, critical literacy, multimodality);
- Theories and principles guiding the design and implementation of ICT-assisted language teaching (e.g., blended learning);
- Theory in practice (e.g., using the Learning Activities Management System or LAMS);
- Educational policy related to the integration of ICT into language teaching and learning.

On completion of this course, the student teachers are expected to

- Articulate and critically analyse ways in which ICT can facilitate English-language learning in line with the Singapore Ministry of Education's English Language Syllabi and ICT Master Plans;

- Explain the relevance of digital literacies in the context of contemporary changes in education and society;
- Apply language learning and literacy theories to the design of lesson plans that strategically incorporate ICT to provide meaningful language learning experiences for students;
- Help their students in the future carry out meaningful digital learning activities with relevant ICT tools.

As such, this course has the following design features. First, it is theory-based. In accordance with Cutrim Schmid's (2017, p. 171) recommendation that "CALL professional development programs should have a sound theoretical basis and a clear pedagogical framework," the student teachers are exposed to various language learning theories, their potential applications to CALL (Youngs, Ducate & Arnold, 2011), and theorization on the relevance of digital literacy to English education in Singapore. This is guided by the premise that advances in second language learning research and digital culture research may offer important guidance and implications to the CALL practitioners (see also Hubbard & Levy, 2006).

Second, the course is experiential and practice oriented. In order to develop into effective teachers in the digital classroom, student teachers "must *first* know how to use them [new technologies] (and any benefits of doing so) for their own authentic purposes" (Lankshear & Knobel, 2003, p. 67, original emphasis) and they need opportunities to create some meaningful digital objects or artefacts. They also need to be exposed to multiple authentic scenarios, where IT is being used for teaching and learning. Efforts were thus made to link the theories discussed to authentic language learning contexts, for example, through organizing field trips to ICT-saturated classrooms in the learning hub (known as the "Hive") at Nanyang Technological University, Singapore, and through a digital storytelling task, where the student teachers were asked to create a 2-min video presentation to promote the National Institute of Education's programmes to an international student audience. Another activity added in 2017 was the use of the Net Gen Learners' Terrace, which integrates innovative technologies that allow virtual consultations, multiple presenters and blended learning in a state-of-the-art classroom.

Third, the course draws on vicarious learning through engaging the student teachers in analysing CALL cases as reported in research articles. CALL activities take place in authentic contexts and can be expected to experience various levels of success. The student teachers need to understand these experiences so that they are better prepared when they are in the classrooms to teach. As Kessler (2013, p. 2) pointed out, "teachers should have some understanding of the common pedagogical implications of CALL-related research. Research investigating the use of computer labs, online environments, and mobile devices in student language learning should be accessible and well known to teachers."

Fourth, we aim to prepare the student teachers to be informed about the conditions for successful technology integration in the schools (Chai & Khine, 2006) that include the contextual factors, for example, the school's technology infrastructure and culture about ICT integration, the Ministry of Education's initiatives and policies about ICT and so forth.

Drawing upon our work in this course over the years and related research literature on CALL teacher preparation such as Hubbard and Levy (2006) and Cutrim Schmid (2017) we would like to address our research questions and put forward the following principles. First, student language teachers need some knowledge of language learning and teaching, as a guide for their pedagogical decision-making. Second, they need first-hand experiences of reading and producing digital projects with a range of digital platforms. Third, they need opportunities to observe and reflect on innovative practices through field trips and through reading relevant research literature. Finally, they need sufficient knowledge about the school (local) contexts that may affect ICT integration in the classroom. In what follows, we describe how some of the student teachers have reacted to three of the pedagogical activities: a field trip to the Learning Hub (NTU), reading and discussion of CALL applications in authentic school contexts, and a class held in the Net Gen Learners' Terrace (NGLT).

7.2.5 Data Collection and Data Analysis

Data were collected from student teachers' posts to Discussion Forums in Blackboard®, a Learning Management System, with their informed consent, for the two e-learning tasks (i.e. tasks that students are expected to complete off-campus via some digital platforms such as Blackboard®). In the first e-learning task during Week 6, the student teachers were asked to read any one of the three articles that describe attempts at teaching multimodal literacies or digital literacies in Singapore (Tan & Guo, 2009; Towndrow & Fareed, 2015) or in-service teachers' engagements with new technology in Hong Kong (Wong, 2013). They were then asked to post their reflections to Discussion Forum. This task was set to expose the student teachers to potentials and challenges that face CALL theories and new literacies discussed in the first 5 weeks. For space constraints, only excerpts that commented on Tan and Guo (2009) were chosen for analysis.

The second e-learning task was conducted in Week 10. The student teachers went on a guided tour to the Learning Hub (NTU) with the assistance from the colleagues of the Teaching & Pedagogy Division, NTU. During the 40-min tour, the student teachers were shown various design features of the Learning Hub. They were then asked to post their reflections/observations to the Discussion Forum in groups of four or five. The general prompts given to the students were: what features did you notice? What kinds of teaching and learning were facilitated? Do you think you might use these pedagogies in your own language classrooms in the future? The student teachers' posts in 2015 and 2017 were selected for analysis.

Another activity held outside of our regular classroom in 2017 was a session conducted during Week 9 in the Net Gen Learners' Terrace (NGLT). Opened in January 2017, the NGLT embodies new learning modes, innovative use of spaces and the emerging popular technologies to support NIE's teaching and learning. It adopts an innovative way of synchronizing video capturing and conferencing such as multiple presenters and co-teaching to support blended learning, flipped classroom and virtual consultation pedagogy initiatives (for more details, refer to https://www.nie.edu.sg/news-detail/new-learning-facility-at-the-nie-campus).

Since one of the aims of our course is to introduce students to new innovations using ICT, it was decided to conduct a lesson at the NGLT during Week 9. With the assistance of our colleagues from the IT Department and Dr. Jenny Lane at Edith Cowan University in Perth, Australia, we held our class there on 19 October 2017. Dr. Lane joined us online and gave a lecture on ICT in Australian schools. Immediate responses from 17 students were collected after the class using Mentimeter (an audience response system using smartphones and useful for collecting immediate anonymous responses) in order to gauge student reaction to the following prompts: (1) What are two things you learned from the session? (2) Reflect on the lesson at the NGLT.

Following Merriam's (2009) advice on the constant comparative method, the student teachers' posts to the Discussion Forum and to Mentimeter were read several times in order to identify common themes in the students' views about the Learning Hub (NTU), the course readings and the session at the NGLT. Attention was paid to identifying evidence that the student teachers have a deep and critical engagement with the issues covered in these three pedagogic activities. In summarizing the student teaches' posts and feedback, repetitive comments among them are reported only once below in order to avoid redundancy.

7.3 Findings: Student Teachers' Reflections on the Course

7.3.1 Reflections on the Course Readings

To provide some brief background, Tan and Guo (2009) documented our experience of working with a secondary school teacher in operationalizing the seminal work on multiliteracies (New London Group, 1996). We describe the measures taken to "transform classroom practices" (Tan & Guo, 2009, p. 316) into fostering critical multimedia literacy in the students, some critical moments where shifts in classroom practices were observed, and challenges facing the teacher and the students when the new pedagogy meets the traditional mode of high-stakes national examinations. The intentions of including this reading into the course were to show the student teachers some of the pedagogical strategies that they could consider adopting in their own classroom in the future and also to alert them to the larger ecology of teaching and learning where more traditional notions of literacy predominate and may hinder the development of multiliteracies in the learners. Thirty-seven (20 from the 2015 class and 17 from the 2017 class) student teachers' comments on Tan and Guo (2009) are summarized as follows.

Student 1 noted from Tan and Guo (2009) that the mode of high-stakes assessment needs change and should cohere with new literacies if new literacies are to be implemented in the classroom. She writes: “While Alicia [the pseudonym of the teacher] agrees and believes that critical multimedia literacy is relevant in the 21st century, the fact that the mode of assessments (e.g., high-stakes language-dominant assessment) remained the same—and thus did not cohere with the critical multimedia literacy lessons—pushed Alicia to prioritise national assessment instead.” “In order to effectively convince teachers to incorporate the teaching of multiliteracy skills into the classroom (or even any other relevant new pedagogies in future), changes must first be made to the modes of assessment—such that ‘what is taught’ and ‘what is tested’ cohere”.

Student 2 focuses on the need for teachers to be trained adequately to teach multiliteracies. She writes: “Teachers have to handle the delicate balance between the need to focus on [traditional] assessment aims and the need to help students become multi-literate language users in this 21st century…. it is critical for in-service and pre-service language teachers to undergo professional training and development to help students understand as well as analyse the various multimodalities available in today’s context.”

In addition to noting the need for the teachers to be equipped with the knowledge of multiliteracy and the weak alignment between curriculum and assessment, Student 3 also highlights the possible reactions from the students. She writes: “Just as how the teacher found it difficult to incorporate critical multimedia literacy skills while preparing her students for exams which do not test those skills, it is likely that students [pupils] would struggle to see the significance of learning those new literacy skills as well since they would not require the skills to do well in the exams.”

Student 4 raises the issue of assessing pupils’ development of multimedia literacy skills, as the traditional print-based language-dominant assessment is clearly insufficient for assessing multiliteracies. She writes: “If a critical multimedia literacy lesson were to really be integrated into the classroom, then one question would be: “How do we assess students’ critical multimedia literacy skills?” We would concur with Student 4: assessment in multiliteracies research has been lagging behind pedagogical innovations (with notable exceptions, e.g., Burke & Hammett, 2009).

Student 5 has noted the four intervention measures that Tan and Guo (2009, pp. 317–319) used to support the teachers: designing the literacy model, designing the literacy activities, designing classroom talk and designing the role of the teacher and the student.

Lastly, Student 6 noted the utility of the conventional assessment when she writes: “these practices are difficult to be done away with as the testing of knowledge is ultimately what sets apart those who require more attention and those who attained enough to progress to higher levels of learning or to the workforce.” She also suggests using new literacy practices/IT to boost the pupils’ performance in the traditional method of assessment.

As we can see, the student teachers have engaged meaningfully with the course reading. Student 2, for instance, makes a point different from Tan and Guo (2009) and Student 4 manages to identify a pertinent issue not highlighted in the original article.

7.3.2 Reflections on the Field Trips to the Learning Hub (The "Hive")

Figure 7.1 presents a photograph of a typical tutorial room in the Hive. In contrast to a traditional classroom design where a teacher's table and a large blackboard are in front of the classroom, facing rows of student desks, this tutorial room is filled with about 7–8 round tables and multiple Liquid Crystal Display (LCD) screens, and a relatively small teacher's console on the side, where the students around the round tables occupy much of the space in the tutorial room and can discuss their ideas with each other and project their work to their individual group as well as to each of the LCD screens for the whole class to view. The student teachers' reflections in groups of 4 or 5 on the field trips to the Hive are summarized as follows.

Group 1 (2017) have noted the affordances of the design of the tutorial room for easy grouping of the students and for discussion. They wrote:

> The classroom settings are such that the teachers would be encouraged to take on the roles of facilitating and the students as active participants. The round tables and many writeable

Fig. 7.1 A typical tutorial room in the Hive

> surfaces would help to stimulate further discussions and the wheeled chairs would help to facilitate to ad hoc regrouping. The arrangement of the screens [LCD screens] around the classroom also allows easy viewing of shared materials which not only promote collaborative work within small groups but also the class.

By "teachers would be encouraged to take on the roles of facilitating," this group means that the teacher's console is on the side in the tutorial room, in contrast to the conventional classroom where the teacher's table is in front and in the centre. This group also noted that in the schools, teachers provide conventional "writeable surfaces when we put up butcher papers around the classroom walls for them to record their brainstorming sessions." They also note that "[i]n terms of seating arrangements, teachers could also explore the various options to arrange the tables and chairs for the pupils to have a better collaborative learning experience."

While noting the above innovative design features, Group 2 (2017) doubted the practicality of this design for a normal primary classroom in Singapore. They wrote:

> Overall, we felt that although the classroom was a great example and benchmark for a collaborative classroom, it still felt like an ideal - impractical, and a touch away from reality for the Singapore primary school. Firstly, because it is expensive to build for all classes in a normal school, and secondly, it would require a lot of time and training for both teachers and students to get used to such technology and set-up. Hence, although a nice idea, it does not seem to be very realistic or practical for the average school.

Group 1 (2015) has noted the potential of the new tutorial room design to support the pedagogy of the flipped classroom. They wrote:

> The new classrooms support the "flipped classroom" pedagogy, where knowledge transfer from teacher to students takes place before class through various online materials that students can access in their own time. Class time is then better utilised as students actively engage their professors and classmates in discussions and debate, instead of being passive recipients of information.

In response to the task prompt "How can you teach the English language if you are a teacher there?" Group 2 (2015) believe that they are able to make use of the facilities to foster collaborative learning. They wrote:

> As an English language teacher, I [sic] would fully utilise the collaborativeness [sic] of the classrooms. Students would be broken into small groups and then given tasks such as Jigsaw or MLEA [Modified Language Experience Approach, part of the STELLAR programme, MOE, 2018] writing exercises. They will then be able to share what they have done on the LCD screens and their peers can then give feedback to what they have done. I can also showcase what they have done on the main projector to highlight common mistakes or good points.

In summary, we can see the student teachers have taken note of the innovative spaces for learning afforded by the design of the Hive, for example, round tables, multiple LCD screens, reduced teacher's console/table that would facilitate collaborative learning and discussion. They also commented on the applicability of these features to their own future classrooms and their capabilities to utilize these features in their classroom if they have access to them.

7.3.3 *Reflections on the Class Held in the Net Gen Learners' Terrace (NGLT)*

As mentioned above, the NGLT has several innovative features: video conferencing functions, group-based conference units, and four LCD screens which facilitate collaborative sharing. The purpose of our Week 9 lesson was to let the student teachers experience this new type of classroom by conducting our regular lesson there with the addition of a guest speaker, Dr. Jenny Lane who joined us from Edith Cowan University (ECU) in Perth, Australia.

The topic of the lesson was design and implementation of lesson plans and the class had watched a video lecture before coming to class (Note: in 2017 we introduced a flipped class format and saw the students for a 2-hour tutorial once a week after they have watched a video lecture online). We had scheduled our guest speaker, Dr. Lane from ECU to speak at the beginning of the class. She gave a lecture on how Australian pre-service teachers are prepared to use ICT in the classroom. Students proceeded to have their regular class using the enhanced features of this new facility. At the end of the class, the following two questions were asked using Mentimeter: (Seventeen student teachers attended that day and due to space constraints, collated comments were added which were indicative of the overall responses).

The first question asked was "What are two things you learned today?" Since this was the first time they had been introduced to the facility, the responses reflected the range of possibilities:

> How to use Cisco Spark; It is possible to conduct lectures with someone overseas; deeper learning approaches; using Cisco Spark as a collaborative tool; usefulness in discussions; new interactive tool.

The second question was to provide general feedback on the day's lesson. Responses were mainly positive, with a couple of remarks on how the lesson could have been improved; "Different and engaging, never knew of such platforms; having a guest speaker was conducive for lessons; wonderful lesson which allows us to incorporate ICT in class; I love this Cisco place; we can talk to people overseas." Areas for improvement included; "Transitions could be smoother, right now we are just exploring; it would have been better to split the tasks into more than one lesson."

Though this was one introductory lesson using this new facility and the feedback received from the students was collected spontaneously at the end of the session, the students remarked on areas that could be relevant for uses of telecollaboration (O'Dowd, 2015). We would also suggest that in classrooms of the future, pedagogic activities include incorporating such a tool for overseas collaboration and classroom discussions. The pedagogical innovations we introduce them to in our course may become part of their regular classrooms. Further use of the NGLT can include more in-depth reflection from students as to how they could incorporate the activities into their future classrooms.

7.4 Discussions and Conclusions

Drawing on the extensive work on CALL competencies (e.g. Hubbard & Levy, 2006; TESOL, 2009), CALL teacher education pedagogy (e.g. Cutrim Schmid, 2017), teacher education (e.g., Grossman et al., 2009) and our own experience of working with pre-service teachers in Singapore, this chapter has argued that it is important for the student teachers to (1) develop some understanding of the principles of language learning to serve as some guidance for their teaching practice; (2) develop some knowledge and practical skills in working with a range of ICT applications in the language classroom; (3) be familiar with the key literature reporting on other teachers' experience with integrating ICT in the language classroom; and (4) have sufficient knowledge of the local context that may affect ICT integration in their classrooms. This argument rests on the premises that teaching languages with technology is a complex social practice (Grossman et al., 2009) involving students, teachers, technological tools, materials and pedagogical considerations (Kessler, 2017) and that teacher education programmes should provide sufficient space and scaffolding experiences for the student teachers to gain mastery of the competencies to function effectively in the classroom. Our own efforts described above have featured "a balance of theory and practice" (Kessler, 2017, p. 114) and encouraging student teachers to critically reflect on innovative classroom practices (García-Martín et al., 2016). Their reflections have in part shown that their understandings have deepened, which may, in turn, help them to effectively teach the English language with technology in the future.

Further, as an extension of the field trips to the Learning Hub and conducting a lesson at the NGLT described above, it will be useful for the student teachers to observe how experienced teachers in authentic school contexts make use of ICT in language teaching and learn from them by performing some of the pedagogical tasks under their supervision. Telecollaboration and video conferencing could provide students with further ICT experiences useful to them in classrooms of the future. Facilities such as the NGLT could be used for collaborative learning and cross-cultural communication (Hahn & Podlaskova, 2016). Such skills are important in the Singapore context. The MOE initiative, 21st Century Competencies (21CC) recognizes global awareness, cross-cultural skills, communication and collaboration as essential skills for students in an increasingly globalized world (Tan et al., 2017). This would require a closer partnership between schools of education and primary and secondary schools (Grossman et al., 2009). Due to time and administrative constraints, we have not been able to explore the potential of the last point but exposing student teachers to actual classroom ICT applications and learning from experienced teachers will provide them with valuable learning experiences.

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Chapter 8
Computational Framework for Modelling Student Engagement in a University's Team-Based Learning Ecosystem

Divya Venkatraman, Huaqing Hong, Andy Khong, and Paul Gagnon

Abstract This chapter presents a learning analytics framework aimed at discovering salient factors that influence learning outcomes in a self-directed team-based learning (SDL-TBL) environment. The data used in this study consists of online logs and formative assessment scores from Year 1 and Year 2 curricula across two cohorts of students at the Lee Kong Chian School of Medicine, Nanyang Technological University, Singapore. Firstly, descriptive analytics was performed on the frequency of online access to learning materials and individual readiness assessment (iRA) scores, independently, to compare the distribution of engagement features and iRA scores of the two cohorts. Secondly, to find the significant factors influencing learning, a predictive analytics layer was built using the engagement features to predict the learner's iRA scores. Next, regression analysis was performed using boosted decision trees, both at the module and lesson-level to gain insights into factors of learner's engagement that could influence their performance. Independent models were then built to predict aggregated mean iRA scores per module and iRA scores at each TBL lesson, using long-term and short-term engagement features, respectively. From the analyses, it is observed that short-term learning outcomes are influenced by engagement with media-based materials, whereas long-term learning outcomes are influenced by engagement in terms of downloads. Additionally, cumulative and consistent engagement were found to emerge as better predictors than promptness in engagement.

Keywords Computational framework · Modelling · Student engagement · Team-based learning

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8.1 Introduction

With the advent of advanced technology, learning at universities that was once constrained to lecture-halls, laboratories, and classrooms, has transformed into any time, anywhere learning (AAL). Many tertiary institutions are restructuring their instructional systems in a way that the students' in-class time consists of activities higher up in Bloom's taxonomy (Krathwohl, 2002), where they engage in higher order skills such as applying, analysing, and evaluating the knowledge acquired. Self-directed learning-team-based learning (SDL-TBL) is one such pedagogy that has been reported to have positive benefits for medical education (Thompson et al., 2007).

A typical team-based learning (TBL) lesson has three main phases (Rajalingam et al., 2018), as illustrated in Fig. 8.1. The students are assigned learning materials for self-study prior to attending their team-based learning (TBL) lessons. A typical TBL lesson at the Lee Kong Chian School of Medicine (LKCMedicine), Nanyang Technological University (NTU), Singapore, is structured by a readiness assurance process (RAP) comprising an individual readiness assessment (iRA) and a team readiness assessment (tRA) (Gagnon, Mendoza, & Carlstedt-Duke, 2017). At the start of a TBL lesson, each student completes an iRA quiz independently and submits these individually completed assessments online. However, they do not know their itemized scores for each question. Next, the students get into their prescribed teams and attempt the same set of questions as a team, this time to get a tRA score. The iRA and tRA are followed by an application exercise (AE) that is guided by a TBL facilitator. The purpose of the RAP is to hold students accountable for reading the TBL preparatory materials and subsequently facilitate their preparedness for the AE that follows.

This study aimed at understanding online learning engagement in a team-based learning ecosystem and mapping such engagement to learning outcomes as measured by individual readiness assessments in the class. The student learning behaviours were analysed using data collected from two cohorts of students over the first two years of their medical education in an SDL-TBL ecosystem created specifically for LKCMedicine. The data for analysis is obtained from the operational learning management systems (LMS).

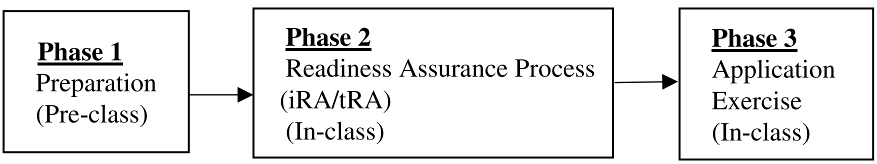

Fig. 8.1 A typical three-phase team-based learning lesson

8.1.1 Purpose of This Study

The key research question guiding this study is: “What are the significant factors that influence student outcomes in a team-based learning system?” To answer this research question, the scope is limited to analysing the relationship between (i) Learning activities, that is, the individual learning behaviour quantified in terms of engagement features with the learning materials on different learning management systems, and (ii) Learning outcomes, that is, the learning outcomes quantified in terms of the individual readiness assessment scores. Since the curriculum comprises 10 modules of study, to exploit this structure, the learning behaviours and the corresponding outcomes were analysed at two levels: (i) long-term or module-level, and (ii) short-term or lesson-level. The learning analytics framework adopted is shown in Fig. 8.2.

Descriptive analytics was first carried out on engagement features that quantify students’ learning behaviour. Analytics was then implemented on the iRA scores that quantify learning outcome achievement. The engagement features that quantify different aspects of engagement such as cumulation, consistency and promptness were defined. Using these newly defined engagement features, regression models were developed to predict whether iRA scores identify significant engagement factors that affect learning outcomes.

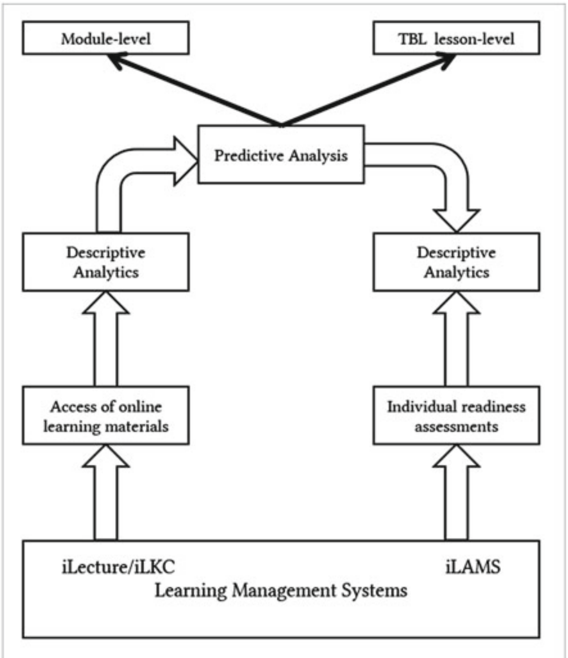

Fig. 8.2 The learning analytics framework adopted for the study

The chapter is structured as follows: in the second section, a review of existing and related literature is presented. The curriculum and the operational LMS are summarized in the third section. The distribution of engagement features that quantify learning behaviour across different modules of study, and across different cohorts are analysed in detail in the fourth section. The distribution of iRA scores as learning outcomes are investigated in the fifth section. Next, engagement-based features are defined that measure different aspects of student's engagement with learning. The significant engagement factors that influence formative performance are identified, using regression with a decision tree-based approach, in the sixth section. Furthermore, the regression analyses performed at the two levels are analysed. The final section concludes the chapter with the suggestion of possible future studies.

8.2 Related Works

Learning analytics (LA) is the measurement, collection, analysis and reporting of data about the progress of learners and the context in which learning takes place, for the purpose of understanding and optimizing learning. One of the popular LA problems is the prediction of students' performance. In the literature, such predictions are targeted at final summative assessment grades (Bekele & Menzel, 2005; Meier, Xu, Atan, & van der Schaar, 2016). There are several studies investigating the predictive power of standardized tests (Cohn, Cohn, Balch, & Bradley, 2004; Julian, 2005) and admissions exams (Gallagher, Bomba, & Crane, 2001) in predicting the academic success of students in both undergraduate and graduate schools. Most of them show a positive correlation between these predictors and summative performance measures in terms of Grade Point Average (GPA) or degree completion. Other studies exclusively use data from the course itself such as performance in formative assessment (Krasne, Wimmers, Relan, & Drake, 2006) and homework assignments (Meier et al., 2016) for prediction.

Study habits or learning activities are found to significantly influence e-learners' performance (Akdemir & Koszalka, 2008; Sharpe & Benfield, 2005). Study habits include a variety of learning behaviours: managing time, setting appropriate goals, choosing an appropriate study environment, using appropriate note-taking strategies, choosing main ideas and organization (Proctor, Prevatt, Adams, Reaser, & Petscher, 2006). Initially, because of the limitations of online LMS logging, no significant relationships were found between learning style and learning performance in online learning (Neuhauser, 2002; Schellens & Valcke, 2000). However, later works found that different learning styles were associated with significantly different learning outcomes (Lafifi, Halimi, Herkas, Ghodbani, & Salhi, 2009; Shaw, 2012). Massive Open Online Course (MOOC) systems use information about video-watching behaviour and time spent on specific questions or forum activity (Brinton & Chiang, 2015; Lopez, Luna, Romero, & Ventura, 2012; Koh et al., 2019) to predict final grades.

Self-directed team-based learning (SDL-TBL) is a pedagogical approach that is gaining popularity, especially in medical education (Rajalingam et al., 2018). There has been limited research targeted at using learning analytics for a TBL ecosystem. Most of these studies in the literature focused on either predicting final summative assessment grades in university courses or predicting performance or drop-out rates in online courses. This limits the transferability of the findings to different educational scenarios. Furthermore, in an SDL-TBL system, the focus is more on the performance of formative assessments than summative assessments. Hence, it is essential to develop models for predicting formative assessments in SDL-TBL systems.

This study is the first step towards developing a learning analytics system for an SDL-TBL ecosystem. Towards this greater objective, this chapter focuses on developing models to predict performance in formative assessment (individual readiness assessment), which students take at the start of every lesson. It is important to note that the prediction analysis is not directed at best accuracy but at identifying the factors that influence student's formative performance. Making use of the structure of the curriculum, the prediction is performed at both module level and lesson level to gain insights into the short-term and long-term factors that influence students' performance. Prediction of formative assessment will enable instructors to plan suitable interventions towards supporting summative performance as the instructors are equipped with information progressively throughout the lessons with formative assessments.

8.3 Operational Setup

8.3.1 Curriculum Structure

The learning behaviours of medical students during the first and the second year of their medical education were analysed. The data was obtained from two cohorts of students labelled C13 (Cohort 2013) and C14 (Cohort 2014), with a cohort size of 54 and 79, respectively. The students studied 10 core modules over a 2-year period. Each module is comprised of multiple TBL lessons across several weeks as summarized in Table 8.1. The number of TBL lessons per module varied a little between the two cohorts. The five modules studied in Year 1 were the following:

- IMS—Introduction to Medical Science,
- CR—Cardiorespiratory,
- IMS2—Introduction to Medical Science 2,
- RE—Renal and Endocrine,
- MSK—Musculoskeletal and Skin.

The five modules studied in Year 2 were the following:

- Intro—Introduction to year 2,
- GBI—GI, Blood and Infection,
- NEE—Neuro, ENT and Eyes,

Table 8.1 Curriculum structure

Year of study	Sem of study	Seq of study	Core module	No. of TBL lessons		No. of weeks	
				C13	C14	C13	C14
Y1	S1	1	IMS	12	12	8	9
Y1	S1	2	CR	19	18	10	10
Y1	S2	3	IMS2	4	4	2	2
Y1	S2	4	RE	22	18	13	12
Y1	S2	5	MSK	15	17	8	9
Y2	S1	6	Intro	2	2	2	2
Y2	S1	7	GBI	23	23	13	13
Y2	S1	8	NEE	16	16	10	10
Y2	S2	9	RMCH	18	18	10	10
Y2	S2	10	MHAF	20	17	10	9
Total:				151	145	86	

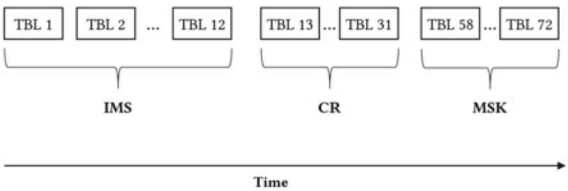

Fig. 8.3 Progression of modules

- RMCH—Reproduction Medicine and Child Health,
- MHAF—Mental health, Ageing and Family.

The modules were introduced to the students one after another in a linear timeline as shown in Fig. 8.3. For example, the IMS module for cohort C13 contained 12 TBL lessons conducted over 8 weeks of study.

8.3.2 Learning Management Systems

The data was obtained from the LMS of LKCMedicine. At the start of the curriculum, all students were issued an iPad to access the learning materials. The students had access to these systems:

- iLecture: A virtual library consisting of a repository of learning materials including lecture videos, interactive multimedia, PowerPoint slides and audio podcasts. Unlike a legacy LMS, iLecture is a book-reading and video-viewing mobile application, which has the ability to log fine-grained information about the student's interaction with the system. The learner's engagement in iLecture is measured by the time spent by the student while accessing various learning materials.

- iLKC: A legacy repository of learning material from which students can download materials and study offline. The learner's engagement with iLKC is measured by the number of learning materials downloaded.
- iLAMS: A system that tracks the student's formative assessment performance such as their iRA, tRA and AE scores for each TBL lesson. Only the iRA is an individual score, whereas the tRA and AE scores are team scores.

8.4 Learning Activities

Since there are two major learning platforms available to the students for their preparation, analysis of learning activities involves the study of learner's engagement with both iLecture and iLKC platforms, for each module of study.

8.4.1 Learner's Engagement in iLecture

Engagement in iLecture can be quantified by the time spent in accessing the media-based learning materials. Using the curriculum structure shown in Fig. 8.3, the iLecture logs are time-sliced according to the module of study.

The total time spent (in hours) per module by all students in a cohort is plotted on the left panel of Fig. 8.4a, b, for cohorts C13 and C14, respectively. Since each module spans a different number of weeks, for a better comparison, the normalized time spent per week for all students is plotted on the right panel of Fig. 8.4a, b, for their respective cohorts. From the plot, it is noted that for both cohorts, the total media time spent is highest for the GBI module, whereas it is less than 30% for RMCH, MHAF and Intro modules. The variation between the cohorts on time spent on the IMS module is because of a delay in the start of logging in iLecture for C13.

Next, the individual media time spent (in hours) per module for each student in C13 and C14 are plotted in Fig. 8.5. From the graph, it is observed that the total media time spent by students in C13 range between 0 and 780 hours, the range is 6–834 hours for C14 students. Table 8.2 summarizes the mean and standard deviation of media time spent per module of study for both the cohorts. The graph and table establish the fact that students' engagement with their learning materials in iLecture is highly individualized.

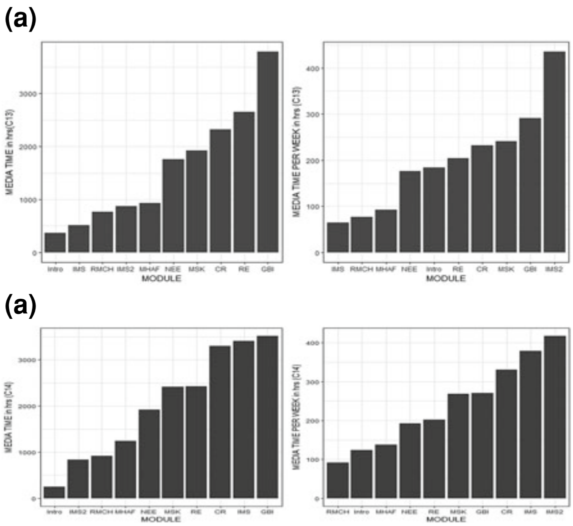

Fig. 8.4 Media time per module on iLecture for **a** C13 and **b** C14

8.4.2 Engagement in iLKC

8.4.2.1 Number of Downloads

In addition to learning from the iLecture platform, students also use iLKC to download learning materials and access them offline for their preparations. Figure 8.6 plots the histogram of the number of downloads per module and the number of downloads from iLKC per module per week across the 2-year period for the two cohorts. The iLKC system started logging activities only from Semester 2 of Year 1 for C13. Similar to the engagement statistics from iLecture, the GBI module has the highest engagement in terms of the number of downloads from iLKC as well. From the C14 histogram, it is noted that the maximum downloads per week happened during the IMS2 and Intro modules. This could be attributed to the fact that both these modules signify the start of a semester when students could be downloading materials in advance for the semester ahead.

Figure 8.7a, b show the number of downloads for each student per module of students for cohorts C13 and C14, respectively and Table 8.3 summarizes the statistics. The number of learning materials downloaded range between 100–1200 for C13 and 180–1300 for C14 over the two-year period.

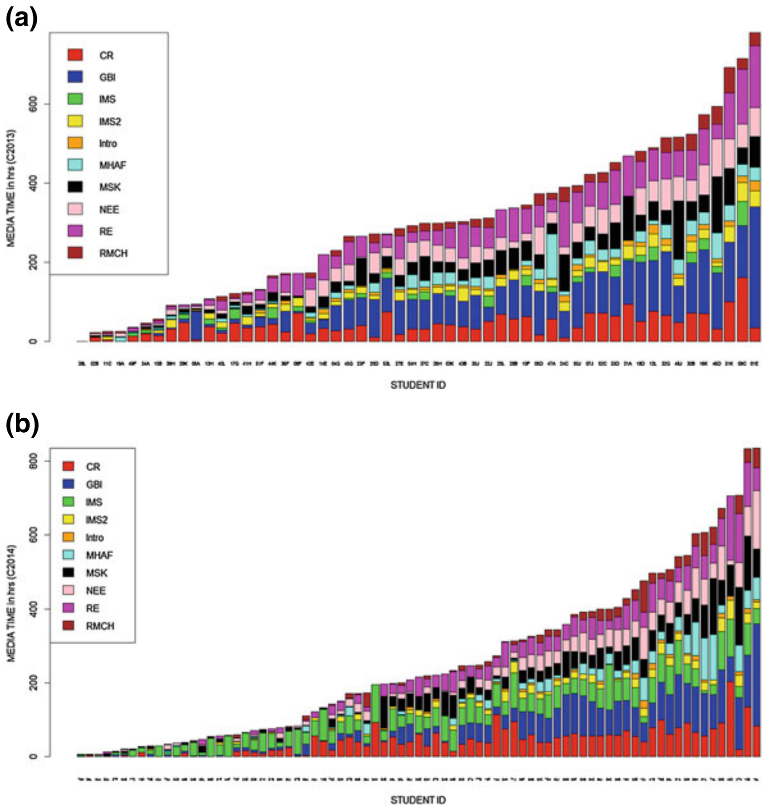

Fig. 8.5 Media time spent per student for **a** C13 and **b** C14

Table 8.2 Media time statistics from iLecture for C13 and C14

Module of study	Mean (C13)	Std. Dev (C13)	Mean (C14)	Std. Dev (C14)
IMS	9.506	12.528	43.176	26.995
CR	43.039	29.134	41.791	36.600
IMS2	16.109	10.837	10.557	10.932
RE	49.089	36.615	30.67	32.244
MSK	35.689	33.266	30.573	34.750
Intro	6.8064	6.0346	3.138	4.4986
GBI	70.179	58.879	44.482	51.454
NEE	32.542	25.917	24.347	29.023
RMCH	14.26	14.274	11.629	16.807
MHAF	17.188	19.766	15.713	25.253

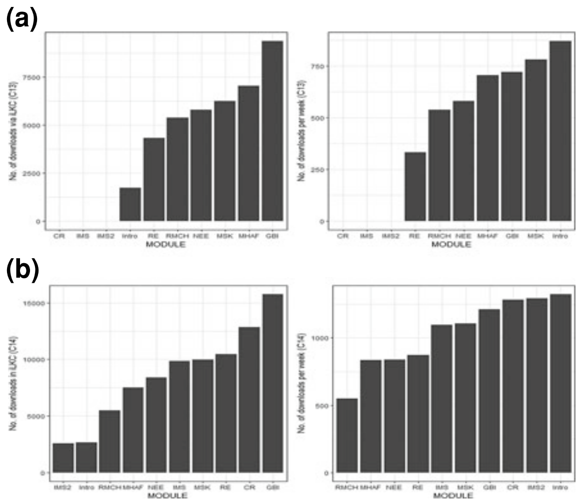

Fig. 8.6 No. of downloads per module for **a** C13 and **b** C14

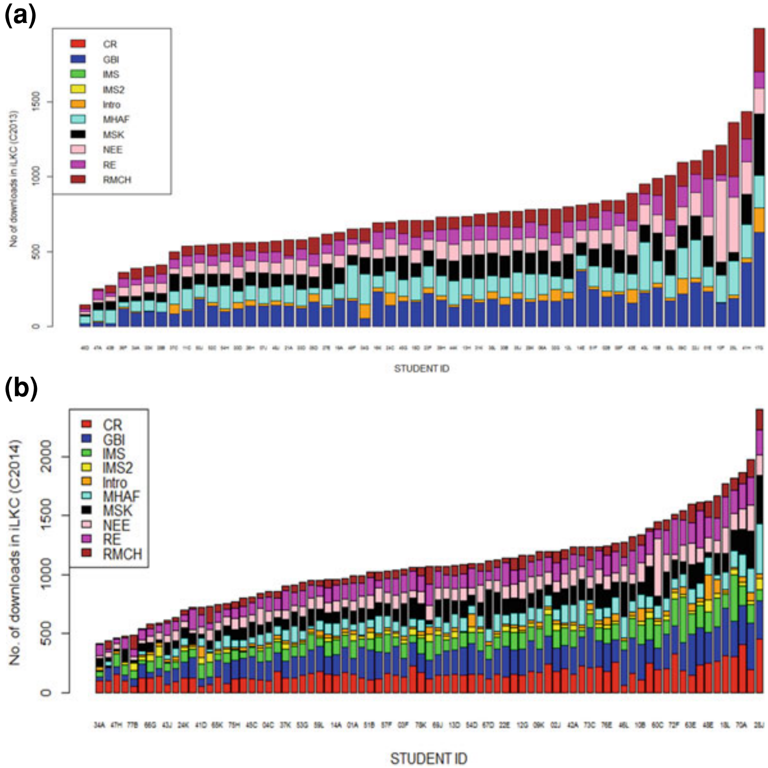

Fig. 8.7 Number of downloads per student **a** C13 and **b** C14

Table 8.3 Download statistics from iLKC for C13 and C14

Module of study	Mean (C13)	Std. Dev (C13)	Mean (C14)	Std. Dev (C14)
IMS	0	0	124.911	60.972
CR	0	0	162.544	71.433
IMS2	0	0	32.785	20.314
RE	80.055	38.57774	132.392	56.213
MSK	115.796	60.46717	126.126	69.791
Intro	32.241	30.17367	33.494	30.83
GBI	173.611	96.52616	199.25	79.486
NEE	107.389	80.00434	106.20	59.411
RMCH	99.704	66.16778	69.405	38.284
MHAF	130.648	56.57593	94.962	60.502

8.4.2.2 Types of Download

From the statistics discussed above, it is evident that different students have different learning preferences. It is possible that some students prefer accessing the iLecture since it has more media-based learning material, whereas other students prefer accessing iLKC to download reading materials. Although iLKC contains both reading materials (*.docx, *.html, *.pdf, *.xlsx) and media materials (*.MP4, *.MOV, *.pptx), we note from Fig. 8.8 that the number of reading materials being downloaded from iLKC is more. This shows that students tend to access iLecture for visual learning materials and access iLKC for verbal learning materials.

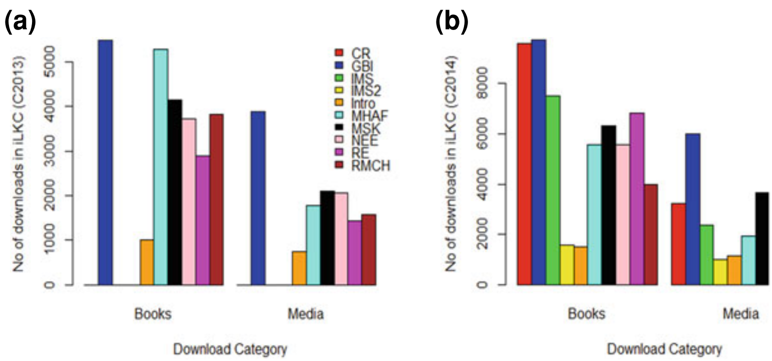

Fig. 8.8 Download category per module for **a** C13 and **b** C14

8.5 Learning Outcome

The individual readiness assessment (iRA) is a formative assessment of the students' skill levels at the beginning of each TBL lesson. The iRA is usually a set of 20–25 multiple-choice questions, answered by the students using their iPad. It is a closed-book time-bound assessment conducted during the first 30 min of TBL lessons. The assessment questions focus on important concepts presented in the preparatory materials. The iRA scores are categorized into three scales—high score (85–100%), medium score (65–80%) and a low score (<65%). Since low scores are indicative of poor learning, the focus is on understanding the module-wise distribution of low scores. The ratio of the number of low scoring TBLs to the total number of TBL lessons in each module is calculated to find the relative percentage of low scoring TBL in each module.

The distribution of low scoring TBL corresponding to different modules of study is listed in Tables 8.4 and 8.5 for cohorts C13 and C14, respectively. From the tables, it is noted that CR in Y1 and RMCH and GBI in Y2 are low scoring modules. The iRA performance also varied between the cohorts. For example, MSK is a low scoring module only in C13, while RE is a low scoring module only in C14.

Table 8.4 Distribution of low scoring TBL for C13

Modules in Y1	Relative % of low scoring TBLs	Modules inY2	Relative % of low scoring TBLs
CR	23.976	GBI	11.594
IMS	13.426	Intro	9.259
IMS2	13.426	MHAF	9.053
MSK	14.938	NEE	5.671
RE	8.187	RMCH	14.403

Table 8.5 Distribution of low scoring TBL for C14

Modules in Y1	Relative % of low scoring TBLs	Module in Y2	Relative % of low scoring TBLs
CR	23.91	GBI	20.748
IMS	10.338	Intro	31.646
IMS2	12.658	MHAF	15.506
MSK	17.498	NEE	11.709
RE	24.684	RMCH	25.738

8.6 Prediction of Learning Outcome from Learning Behaviour

In order to find factors that affect the learning outcome, a regression model is built to predict the iRA scores (learning outcome) using engagement-based features (learning behaviour) discussed in the previous section. Based on the structure of the curriculum (shown in Fig. 8.2), regression analysis is performed at two levels:

- At *Module-level* to predict module-wise aggregated mean iRA score using module-wise engagement features.
- At *TBL lesson-level* to predict TBL lesson IRA scores, using TBL-wise engagement features.

The engagement-based predictors in the regression can be categorized into three broad categories:

1. Cumulative features that measure the aggregated amount of engagement, that is, MEDIATIME_HRS which is defined as the total media time spent in iLecture for a whole module of study for module-level regression, or as the media time spent for a particular TBL lesson (from the previous TBL lesson) for lesson-level regression.
2. Consistency features that measure the rate of learning, that is, MEDIA_PER_DAY which is calculated as the ratio of total media time spent in the iLecture system to the number of active days for module-level regression. For lesson-level regression, it is calculated with respect to the TBL lesson.
3. Promptness features that measure the first response of the learners, that is, MEDIADATE_DIFF is calculated as the first active day in iLecture from the official start date of the module of study. For lesson-level regression, it is calculated as the first active day in iLecture with respect to the TBL lesson.

As discussed, there exists a difference in the learning behaviours between the cohorts. To gain better insights into the factors, the prediction is performed using data from cohort C13 and cohort C14, independently. Furthermore, a combined regression model is developed by introducing a COHORT feature, which includes two categorical values (2013 and 2014) to understand the effect of the cohort on iRA prediction.

8.6.1 Methodology

A decision tree-based approach is used for the regression analysis since tree-based methods involve stratifying the predictor space into a number of simple regions that are simple and useful for interpretation. However, decision trees also suffer from high variance. Hence, instead of imposing a single large decision tree to the entire

1. Set $f(x) = 0$ and $r_i = y_i$ for all i in the training set
2. For $b = 1, 2, \ldots, B$, repeat:
   a. Fit a tree f^b with d splits ($d + 1$ terminal nodes) to the training data (X, r).
   b. Update f by adding in a shrunken version of the new tree:
   $$f(x) \leftarrow f(x) + \lambda f^b(x)$$
   c. Update the residuals,
   $$r_i \leftarrow r_i - \lambda f^b(x_i)$$
3. Output the boosted model,
$$f(x) = \sum_{b=1}^{B} \lambda f^b(x)$$

Fig. 8.9 Boosting algorithm for regression trees

dataset which could be contrived as overfitting, the boosting technique is used where decision trees are grown sequentially to fit the data. The first decision tree is built using the whole dataset. Further on, decision trees are fitted to the residuals obtained after the first model. The boosting algorithm (James, Witten, Hastie, & Tibshirani, 2014) for regression trees are summarized in Fig. 8.9. The gbm package in R is used for modelling the data using boosted regression trees. The three tuning parameters for the boosting algorithm are chosen to be the number of trees (B) = 5000, shrinkage parameter $\Lambda = 0.01$ and interaction depth (d) = 4.

8.6.2 Results on Learning Activities versus Outcomes at Module-Level

In this section, regression analysis is performed at the *module-level* to predict the module-level aggregated mean iRA score using module-level engagement features. Table 8.6 lists the engagement-based predictors and how they are calculated.

As discussed above, the predictors measure cumulation, consistency and promptness of the learner's engagement on both media activities in iLecture and download activities in iLKC. The last feature COHORT is used only on the regression model using combined data from C13 and C14.

The results of the boosted regression tree analysis using data from C13 are summarized in the order of relative importance to the engagement predictors in Table 8.7. As expected from the descriptive analytics in the section "Learning Activities", the learning outcome is influenced significantly by the module of study, that is, BLK_NAME. Since downloading learning materials on iLecture did not get logged for the first

Table 8.6 List of features to predict mean iRA score

	Features	Description
1	BLK_NAME (categorical)	The module of study—IMS, IMS2, Intro, RE, MSK, NEE, RMCH, MHAF, CR, GBI
2	MEDIATIME_HRS (iLecture-Cumulative)	Total media time in hours accessing learning material within the module of study
3	MEDIA_PER_DAY (iLecture-Consistency)	Average media time spent per day accessing learning materials within the module of study
4	MEDIADATE_DIFF (iLecture-Promptness)	The difference in days between the start of the module and first active media access day
5	DOWNLOAD_NUM (iLKC-Cumulative)	Count of the number of learning materials downloaded within the module of study
6	DL_PER_DAY (iLKC-Consistency)	The average number of materials downloaded on each active day within the module of study
7	DLDATE_DIFF (iLKC-Promptness)	Difference in days between the start of the module and the first active download day
8	COHORT (categorical)	Cohort to which the data record belongs—2013, 2014

Table 8.7 Module-level prediction using only C13 data

Module-level prediction (C13) No. of records: 540	
Feature	Relative importance
BLK_NAME	26.232807
MEDIA_PER_DAY	22.425773
MEDIATIME_HRS	20.868584
DL_PER_DAY	10.389733
DOWNLOAD_NUM	8.645831
PREPDATE_DIFF	8.397935
DLDATE_DIFF	3.039337

semester in C13, as shown in Fig. 8.5, the module-level prediction produces features based on media time in iLecture as dominant predictors. To make a fair comparison between the cohorts, the records corresponding to the first semester in C13 are removed and a regression model is built on the modified dataset.

Table 8.8 compares the prediction results for modified C13 data and C14 data. For C13, MEDIA_PER_DAY emerges as the most important predictor, in contrast to DL_PER_DAY for C14. Compared to Table 8.7, the DOWNLOAD_NUM has gained significance in the prediction of iRA scores in C13. The module of study emerges as the most important predictor in C14.

Table 8.8 Comparison of module-level prediction of iRA scores in C13 and C14

Module-level prediction (modified C13) No. of records: 378		Module-level prediction (C14) No. of records: 790	
Feature	Relative importance	Feature	Relative importance
MEDIA_PER_DAY	18.628864	DL_PER_DAY	20.430330
DOWNLOAD_NUM	17.982031	BLK_NAME	18.988379
DL_PER_DAY	17.908616	DOWNLOAD_NUM	18.663397
MEDIATIME_HRS	16.589827	MEDIATIME_HRS	17.467059
BLK_NAME	13.567195	MEDIA_PER_DAY	13.161407
MEDIADATE_DIFF	8.429467	MEDIADATE_DIFF	7.128542
DLDATE_DIFF	6.894001	DLDATE_DIFF	4.160887

From Table 8.8, it is observed that both cumulation and consistency of the module-level engagement influence the mean aggregated iRA scores. However, the promptness features turn out to be the least important predictors in both cohorts. Next, a regression model is built using the combined data from C13 and C14. In order to study the influence of the cohort on the iRA score, COHORT is introduced as one of the predictors. Table 8.9 summarizes the combined module-level prediction results.

The COHORT feature does not play a significant role in the prediction of module-level iRA scores. This means that at the module-level the aggregated iRA scores obtained by both cohorts of students are comparable. As expected, the module of study is a significant predictor. Comparing the learning activities, it is noted that engagement with iLKC has a slightly greater influence on the iRA scores than media time spent on iLecture. Furthermore, the consistency of download has a higher influence than the cumulative download. This can be attributed to the fact that consistency includes the number of active days on iLKC. With respect to media time, the cumulative media time spent is more important than the consistency. To gain deeper insights into the factors that influence learning outcomes, fine-grained predictions are performed using TBL-level engagement features.

Table 8.9 Combined module-level prediction results

Module-level prediction (Combined) No. of records: 1168	
Feature	Relative importance
DL_PER_DAY	19.175553
BLK_NAME	18.907458
DOWNLOAD_NUM	17.925758
MEDIATIME_HRS	17.786132
MEDIA_PER_DAY	12.644749
MEDIADATE_DIFF	6.208108
DLDATE_DIFF	4.288050
COHORT	3.064193

8.6.3 Results on Learning Activities Versus Outcomes at TBL Lesson-Level

Regression analysis is performed at the *TBL lesson level* to predict lesson iRA scores, using engagement features between lessons. Table 8.10 summarizes the engagement features for lesson-level prediction. Most of the features are similar to the ones listed in Table 8.5, except that they are calculated using time periods between the TBL lessons. A new feature BETWEEN_DAYS is added to measure the effect of the number of days between the TBL lessons on the resulting iRA scores.

Similar to the previous analysis, a separate regression model is built using C13 and C14 data. Due to the shortcoming in the full dataset of C13, the modified dataset is used for C13. Table 8.11 summarizes the results of regression analysis on the different cohort datasets. Similar to module-level prediction, the module of study has a significant influence on the iRA scores. As discussed earlier, there are some modules that have a comparatively higher number of low scores than others.

Features that measure promptness of engagement remain less significant compared to features measuring cumulative activity and consistency of engagement at the lesson level. However, in contrast to module-level prediction models, the media time spent on iLecture influences the lesson-level iRA scores more than the number

Table 8.10 List of features to predict lesson-level iRA score

	Features	Description
1	BLK_NAME (categorical)	The module of study—IMS, IMS2, Intro, RE, MSK, NEE, RMCH, MHAF, CR, GBI
2	MEDIATIME_HRS (iLecture-Cumulative)	Time spent (in hours) accessing media between the previous lesson to the current TBL lesson
3	MEDIA_PER_DAY (iLecture-Consistency)	Average time spent (in hours) per day accessing media between the previous lesson and the current TBL lesson
4	MEDIADATE_DIFF (iLecture-Promptness)	The difference in days between the first active media access day and the current TBL lesson
5	DOWNLOAD_NUM (iLKC-Cumulative)	Number of learning materials downloaded
6	DL_PER_DAY (iLKC-Consistency)	The average number of downloads per day between the previous lesson and the current TBL lesson
7	DLDATE_DIFF (iLKC-Promptness)	The difference in days between the first active download day and the current TBL lesson
8	BETWEEN_DAYS	Number of days between the previous and the current TBL lesson
9	COHORT (categorical)	Cohort to which the data record belongs—2013, 2014

Table 8.11 Comparison of lesson-level prediction of iRA scores in C13 and C14

TBL lesson-level prediction (C13 Modified) No. of records: 5994		TBL lesson-level prediction (C14) No. of records: 11218	
Feature	Relative importance	Feature	Relative importance
BLK_NAME	19.291786	BLK_NAME	25.247445
MEDIATIME_ HRS	19.198550	MEDIATIME_HRS	15.668156
MEDIA_PER_DAY	18.390101	BETWEEN_DAYS	14.504450
DL_PER_DAY	11.199690	MEDIA_PER_DAY	12.469823
DOWNLOAD_NUM	10.900093	DL_PER_DAY	12.113440
BETWEEN_DAYS	9.647083	DOWNLOAD_NUM	10.619261
DLDATE_DIFF	5.977919	DLDATE_DIFF	6.054229
PREPDATE_DIFF	5.394778	MEDIADATE_DIFF	3.323196

of download features. The new feature BETWEEN_DAYS has a significant influence on C14 iRA scores compared to C13.

A combined regression model is built using data from C13 and C14 and along with the COHORT feature. Table 8.12 summarizes the prediction results from the level-wise prediction model. The module of study emerges as a clear significant influence at the lesson-level as well. Similar to module-level prediction, the promptness features are not significant to predict iRA scores. Unlike the module-level prediction shown in Table 8.10, the COHORT feature emerges as a significant feature. This is because the iRA scores between the cohorts are comparably different. Furthermore, BETWEEN_DAYS features surface as a significant influence on the iRA scores. In comparison to module-level prediction, media-based features emerge more significant than download-based features. However, consistency of download is (more or less?) important than cumulative download, whereas cumulative media time is more significant than the consistency of media access.

Table 8.12 Combined TBL lesson-level prediction results

Lesson-level prediction No. of records: 17212 (Combined)	
Feature	Relative importance
BLK_NAME	23.391428
MEDIATIME_HRS	14.464183
COHORT	12.642285
BETWEEN_DAYS	12.586947
MEDIA_PER_DAY	10.628970
DL_PER_DAY	9.501358
DOWNLOAD_NUM	8.874807
DLDATE_DIFF	4.875701
MEDIADATE_DIFF	3.034320

8.6.4 Discussion

Comparing results in Tables 8.9 and 8.12, it is noted that engagement in terms of download activities influences the module-level prediction of aggregated iRA scores more than engagement with media access. On the other hand, for lesson-level prediction, engagement with media access in iLecture is of greater influence than engagement with iLKC. The above trend signifies the fact that in the short term, students are more likely to consume media-based learning materials from iLecture between their TBL lessons. As the module progresses, the students download learning materials from iLKC. This results in the download feature emerging as significant for the long-term module-level predictions.

It is important to note that learner's consumption of media and downloaded material are not measured on the same scale. Media time is measured in number of hours whereas downloaded material is measured in terms of count and not in terms of time spent on consuming the downloaded material. The LMS does not currently have the capability to record when and how much time the students access the materials downloaded. From the regression analysis, we note that it is important to look at learning behaviour both in terms of engagement with iLecture and iLKC.

Since the module of study BLK_NAME emerged as the dominant influence on the iRA scores, the correlation between the IRA score for each module at the TBL lesson-level is analysed using data from both C13 and C14. Tables 8.13 and 8.14 summarize the correlation coefficient between iRA scores and the cumulative and consistency

Table 8.13 Correlation between iRA and engagement features for Year 1 modules (*p-value < 0.001)

Feature	iRA (IMS)	iRA (CR)	iRA (IMS2)	iRA (RE)	iRA (MSK)
MEDIATIME_HRS	0.065	0.165*	0.1395	0.116*	0.138*
MEDIA_PER_DAY	0.104	0.172*	0.0827	0.140*	0.179*
DOWNLOAD_NUM	−0.029	0.0173	0.0341	−0.12*	−0.009
DL_PER_DAY	−0.008	0.066	−0.0013	−0.04	0.0142
BETWEEN_DAYS	−0.12*	0.104*	0.2004*	−0.11*	0.007

Table 8.14 Correlation between iRA and engagement features for Year 2 modules (*p-value < 0.001)

Feature	iRA (Intro)	iRA (GBI)	iRA (NEE)	iRA (RMCH)	iRA (MHAF)
MEDIATIME_HRS	0.107	0.099*	0.147*	0.096*	0.078*
MEDIA_PER_DAY	0.110	0.122*	0.169*	0.114*	0.079*
DOWNLOAD_NUM	0.133	−0.03	0.014	0.03	0.004
DL_PER_DAY	0.034	−0.04	0.039	0.022	0.002
BETWEEN_DAYS	0.296*	−0.08*	−0.1*	0.089*	0.008

engagement features for Year 1 modules and Year 2 modules, respectively. The tables also indicate the significance of the correlation in terms of the p-value.

From the results, it is observed that there exist minor variations in the module-level correlations between the iRA scores and engagement factors. However, as established in Table 8.13, the majority of the modules have a significant correlation with time spent accessing media in iLecture. It is also observed that the iRA scores are also dependent on the count of days between the lessons.

8.7 Conclusion

The descriptive statistics showed that students in cohort C13 spent 0.6–1.8 h on average every time they accessed the iLecture, whereas students from cohort C14 spent only 0.47–1.3 h for every active day in iLecture. Similarly, students from C13 downloaded 3–5.5 learning materials on average every time they accessed the iLKC, and students from C14 downloaded 2.5–5 materials for every active session. The analysis of the iRA assessment scores showed that for both C13 and C14, 50% of students, who had many low scoring lessons in Year 1 continue to have a higher number of low scoring lessons in Year 2 modules as well.

In this chapter, we have analysed a learning analytics framework to discover the salient factors that influence learning outcomes in a self-directed team-based learning (SDL-TBL) environment. The metric we used as a measure of students' knowledge is the Individual Readiness Assessment (iRA). Our predictive analysis indicates that the salient factors that influence the learning outcomes are different based on the time horizon of analysis, that is, a short-term time period over a lesson, versus a long-term time period over an entire module. The nature of the data we had from the different cohorts manifested as a difference in the learning behaviours between the cohorts. In order to gain better insights into the salient factors, we performed a predictive analysis using data from the cohorts independently. We then developed a combined regression model to understand the effect of the cohort on our predictions and found that the promptness feature was the least important predictor in both cohorts. However, at the module-level, the aggregated iRA scores obtained by both cohorts of students were comparable. Lesson-level prediction in the short-term is influenced by the amount of media access time by the learners. In comparison, module-level prediction in the long-term was influenced by the number of downloads from the repository of learning material in iLKC. It is also identified that cumulative activity and consistent engagement by students have a greater impact on their iRA performance rather than promptness in engagement.

8.7.1 Future Research

In this study, the learning activities of the student were spread across two learning management systems which capture engagement differently. This limited the study in terms of evaluating engagements on the LMS on the same metric. However, we believe that the results of this predictive analysis can be used to improve the effectiveness of Learning Management Systems (LMS). There are two pivots in which LMS could be improved by the results of our work: proactive and reactive. An example of proactive improvement of LMS is that although promptness of engagement is not an indicator of future performance, LMS could have a gamification system embedded to reward students who promptly engage and build to overall consistent engagement with the learning materials. As an example of reactive improvement of LMS, the salient features we discovered, that is, media access time in the short term and number of downloads in the longer term, could be monitored to build an early-warning or intervention system. If these features fall behind the median, students could then be given appropriate recommendations via the LMS itself or a peer-mentor program in a consistent manner. Once the LMS has such features built in, future work can be evaluated or measure the drift of these features and the effective improvement observed for students over multiple cohorts.

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Chapter 9
Learning Analytics in Online Knowledge Building Discourse

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Abstract Learning analytics is an emerging field, enabled by the introduction of *big data* and *analytics*, together with newer aspects of data visualisation. This chapter illustrates the use of learning analytics in Nanyang Technological University, Singapore. A study was conducted to investigate the use of learning analytics and its effects in an online knowledge building discourse, contributed by a group of educational professionals. Scaffolds in the form of thinking cues are provided through the online platform. The analytics include the analysis of usage patterns of scaffolds and the identification of promising ideas in the discourse, which could help students in understanding the key challenges and efforts to sustain idea improvement in a knowledge building discourse. Promising ideas are ideas that have the potential to advance communal knowledge. The Idea Identification and Analysis (I2A) methodology was developed to identify relevant keywords, determines features from the unstructured textual discourse, and identifies promising ideas in discourse using temporal discourse analysis. The effects of analytics results on the community, existential limitations, and concerns are discussed. Overall, the results of the study suggest that students benefited from the usage of learning analytics with discourse analysis in the practice of knowledge building.

Keywords Learning analytics · Knowledge building · Discourse analysis

9.1 Introduction

Although discourse analysis has long been conducted to inform the design and improve the productivity of knowledge creation, the use of emergent analytics has hastened these processes. In recent years, the concepts of *big data* and *analytics* have created an ardent following and gained popularity among researchers. Big data is a term often used to refer to the collection and storage of large quantities of data.

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To some, big data is part of a revolution to transform how humans live, work, and think (Mayer-Schönberger & Cukier, 2013), due to the potential of insights that can be generated from data to influence society and science. To handle and infer meaningful interpretations from the ever-increasing amount of data, analytics, in newer forms and methodologies, are continually being developed.

As new technologies continue to be explored for research, teaching, and learning purposes in educational institutions, the way students communicate and interact with one another is being transformed. At the same time, the use of technologies generates a trail of data that contains information about various aspects of individual or collaborative learning, such as studying patterns and learning environments. This data is often stored alongside information about learning outcomes, such as grades, written work, and feedback, which can be harnessed by researchers for studying patterns in student behaviours (e.g. Talavera & Gaudioso, 2004). Other administrative and operational data can be analysed as part of a big data framework to efficiently utilise data to shape the future of higher education (Siemens & Long, 2011). Scholars have argued that a combination of a big data framework together with learning analytics might be able to inform strategic decision-making regarding resource allocation for educational excellence (Macfadyen & Dawson, 2012).

As a result of the potential applications and impact, learning analytics, as a nascent field, has generated strong interests among educational researchers and practitioners (Johnson, Smith, Willis, Levine, & Haywood, 2011; Siemens, 2013). Some applications include processes that analyse discussions to inform design and improve productivity of knowledge creation (Chiu & Fujita, 2014), and analysis of social discourse networks, using methods such as social network analysis (SNA; Scott, 2017; Wasserman & Faust, 1994) to gather further insights into the quality of interactions between discourse participants.

Learning analytics for understanding discourse, aptly termed as discourse-centric learning analytics (De Liddo, Shum, Quinto, Bachler, & Cannavacciuolo, 2011), draws from both sociocultural discourse analysis and argumentation theory to focus on learners' discourse as a site for identifying activity patterns, annotations, and relevant contributions that can lead to derivation of meaningful conclusions and understanding. This chapter illustrates the use of learning analytics in discourse analysis and for the understanding of online discourse contributed by a group of educational professionals in a graduate course. The learning analytics include scaffold usage analysis and an idea analysis of a knowledge building discourse with further investigation on the effect of the learning analytics on the discourse. Guiding this study is the research question: "What are the effects and implications of learning analytics, such as scaffold and idea analysis, on online discourse in a higher education setting?"

9.2 Background

9.2.1 Knowledge Building Discourse and Analysis

This study was conducted with a graduate course on computer-supported collaborative learning and knowledge building. It is pertinent to first explain the concept of knowledge building as a pedagogy. As we move into the *knowledge age* (Bereiter, 2005), the health and wealth of a society depend on the capacity of the workforce within a society to innovate. In order for students, the future workforce, to remain relevant in a dynamic world and continue to be knowledge creators, following current approaches such as "learning-by-doing" and cognitive apprenticeship may not be a feasible option (Reigeluth, 2013).

Pioneered by Scardamalia and Bereiter (2003), the implementation of knowledge building often starts with a trigger event that prompts the students to start an inquiry in authentic situations. The teacher encourages inquiry that is "fundamentally open or divergent…in terms of allowing a broader degree of uncertainty in what would constitute an adequate answer" (Burbules, 1993, p. 97). Students' inquiry questions are followed by initial ideas put forth by the students in an attempt to provide explanations or answers to the questions. An *idea* refers to a unit of thought that can be a question, an explanation, an observation, or an opinion. A technology platform (e.g. an online forum) can be used for students to represent their ideas using semiotic resources (e.g. text or graphics). These ideas are captured as knowledge artefacts in the shared platform. The shared platform allows the students to work on their ideas and to keep improving their ideas or propose new ideas. Overall, the students are engaging in a collaborative idea improvement process that is captured by the shared platform. The idea representation also provides concrete knowledge artefacts that the students can use for their revision.

Knowledge building, as an alternative pedagogical approach, provides students with an opportunity to attain deeper understanding, contribute to the communal discourse, and eventually assist the advancement of communal knowledge. Knowledge building plays a role in inducting students into a knowledge building community, where they engage in knowledge creation by building on one another's ideas. Knowledge building can be considered an alternative perspective of how students can integrate sense-making and understanding of the world with a broader view of learning, as compared to the traditional perspective of seeing learning as main retention of knowledge in the long-term memory (Kirschner, Sweller, & Clark, 2006). Students will be able to achieve a deep approach to learning (Biggs, 1987) and use the most appropriate cognitive activities for handling learning tasks while constructing new knowledge and understandings based on what they already know and believe (Bransford, Brown & Cocking, 1999).

Considering the growing trend of student interactions and discourse that take place in online spaces, it is critical that efforts be extended beyond the analysis of verbal discussions in classrooms to the analysis of online discussions, to inform the design and improve the productivity of knowledge creation (Chiu & Fujita, 2014). Even though the approach of framing and co-constructing of knowledge through technology has been established for some time (Cohen & Scardamalia, 1998), given the current state-of-the-art technology in analytics, there are opportunities and affordances that allow analysts to continue exploration and investigations of textual features and attributes within an online discourse.

There are challenges to the implementation of knowledge building in both K12 and higher education settings. While K12 discourse is lamentably and often dominated by concerns about high-stakes examination, discourse in higher education settings tends to gravitate towards the ever-popular debate on accessibility and affirmative action (Kirst & Venezia, 2004), with few established models or approaches to guide students towards innovating or creating new knowledge (Griffin, Holford, & Jarvis, 2013). This chapter focused on the analysis of higher education discourse, using learning analytics to understand the process of learning and more specifically, recognise how students represent and co-construct their knowledge through the improvement of ideas in discourse.

9.2.2 Idea Analysis in Discourse

Since discourse is considered an interactive process of conveying ideas (Schmidt, 2008), it is also intuitive to use and analyse ideas within discourse for understanding the content and context of the discourse. This concept of understanding discourse using ideas can be found across different fields, such as using idea analysis to show mathematics' raison d'être (Nuñez, 2000) and analysing ideas as part of explanations in political science (Schmidt, 2008). In the context of knowledge building, the principle of "improvable ideas" (Scardamalia, 2002) through inquiries and productive discourse encourages students to value every contribution and idea within discourse as being potentially improvable. By analysing an idea-centric knowledge building discourse, students and teachers are provided with the necessary information to recognise, acknowledge, and navigate through knowledge gaps and emergent themes of inquiries from multiple sources of inputs (Zhang, Scardamalia, Reeve, & Messina, 2009). As an example, the dynamics of ideas in a knowledge building discourse in this chapter were explored using part of an Idea Pipeline framework, developed by Lee and Tan (2017a), that enabled discourse participants to recognise ideas that are potentially interesting to the community. The usage of the Idea Identification and Analysis (I2A) methodology in the framework is hereby presented in this chapter as part of the study.

9.2.3 Role of Learning Analytics in Knowledge Building

In recent years, the application of learning analytics in discourse analysis is gaining traction and has significant implications for the learning community, especially when conducted within the context of a knowledge building environment. Knowledge building was introduced into Singapore as a pedagogical approach that recognises knowledge to be socially constructed, with a focus on collective cognitive responsibility by all within a learning community, in order to achieve communal knowledge advancement.

The motivation for using learning analytics in knowledge building discourse stems from the need to assess the efforts extended to the community during knowledge building activities, and the subsequent impact on communal understanding within a knowledge building community. Current efforts in assessing knowledge building discourse include temporal analysis of discourse to discover productive discussion threads (Chen, Resendes, Chai, & Hong, 2017), and network and temporal analysis (Lee, Tan, & Chee, 2016; Lee, & Tan, 2017b) that focused on finding communally promising ideas from knowledge building discourse. These studies have a common goal in mind: to show the actualisation of learning through dialogue and discourse, and assist participants in understanding the key challenges of sustainable idea improvement in a knowledge building discourse, by identifying productive discussion threads and promising ideas.

Promising ideas are beneficial for a discourse community to improve their understanding, and more importantly, for a knowledge building community to advance communal knowledge. However, some effort is still required in order to sustain the community's interest in said ideas and therefore, scaffolds as thinking cues can be used to elevate discourse participant's interest of ideas in the discourse, and to also have some form of impact or influence on communal discourse. Other than conducting an analysis of scaffold usage, the Idea Identification and Analysis (I2A) methodology is also introduced and used in the following ways: (a) to discover relevant keywords from unstructured textual discourse, (b) to determine features and measures of the discourse network using the keywords, and (c) to identify promising ideas in discourse using temporal discourse analysis. A part of the research question can be answered by determining the relationship between the quality of ideas and the use of scaffolds in knowledge building discourse. The results of the study suggest that considerable benefits were gained from the use of learning analytics with discourse analysis in the practice of knowledge building and its subsequent implementation in the teaching and learning cycle.

9.3 Methods

This section explains the suite of methods that were used in this study. Starting with an analysis of the type and patterns of scaffold usage in Knowledge Forum, a more in-depth analysis was subsequently conducted using methods from the I2A methodology to identify promising ideas from the previous week's discourse that can be highlighted to students for further discussion. The visualisations of the analyses were presented to the students, and their subsequent discourse for the following week was then monitored, recorded, and analysed to detect any changes to the students' discourse and scaffold usage. The different methods used in this chapter are explained in greater detail in the following subsections.

9.3.1 Settings, Data, and Schedule

A graduate course was offered to educational professionals (lecturers, teachers, and trainers). During the course, the students participated in an online knowledge building discourse that spanned 13 weeks, of which the first week and last two weeks of discourse were used for administrative purposes. Thus, only 10 weeks of discourse data were extracted for analysis. The discourse data consists of contributions from 13 students and 2 teaching staff.

In this course, the graduate students learnt about computer-supported collaborative learning (CSCL) and knowledge building (KB) by experiencing first-hand as a knowledge builder in a learning environment. At the start of the course, the students were encouraged to think of an authentic problem or conceptual issue related to learning, which they encountered in their work or learning environments. By identifying these authentic problems, the students could then put forth their ideas within a designated online forum called Knowledge Forum (Scardamalia, 2004). The students contributed their ideas on Knowledge Forum, which provides an online space for students to express their ideas as notes (a form of knowledge artefacts). As students write and view notes that were contributed by other students, they would be able to collaboratively improve on and integrate each other's ideas, often resulting in a *rise-above*, a process in which students synthesise new ideas and use higher level principles or theory in their explanations and with deeper understanding. Knowledge Forum is thus a platform that makes the trajectory of students' idea improvement visible.

The source of data for this study was the textual discourse found in student-authored notes. To monitor the effect of analytics on subsequent student discourse, an analysis of the discourse in the previous week was conducted and the results were shown to students in the class, and the impact of analytics on the discourse analysed and reported in the following week. Figure 9.1 illustrates the schedule of data collection and analysis in three consecutive weeks.

As the duration of one cycle of data collection and analysis took about two weeks, four datasets were collected from the whole duration of the course. Table 9.1 shows the schedule of this study for collecting and analysis of discourse data. The findings in the following findings section would also be presented in a similar manner.

In sum, a report was generated every fortnight, starting with an analysis of scaffold usage in Knowledge Forum. The textual discourse was then mined to discover conceptual keywords, which were used as features for deeper analysis using social network and temporal analysis. Promising ideas were identified, and further analysis was conducted to determine the relationship between scaffold usage and quality of ideas in knowledge building discourse.

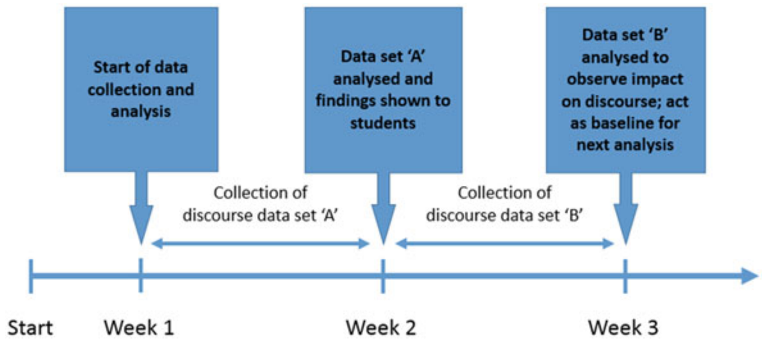

Fig. 9.1 Visualisation of the timeline for one cycle of data collection and analysis

Table 9.1 Deliverables from collection and analysis of discourse data for this study

Timeline	Week 4	Week 6	Week 8	Week 10
Deliverables	Report on the impact of Week 2–3 analysis on Week 3–4 discourse	Report on the impact of Week 4–5 analysis on Week 5–6 discourse	Report on the impact of Week 6–7 analysis on Week 7–8 discourse	Report on the impact of Week 8–9 analysis on Week 9–10 discourse

9.3.2 Calculation and Visualisation of Scaffold Use in Knowledge Forum

Textual discourse data found in the notes are timestamped, and the authorship details can be used for both visual and content analyses. Some of these textual data are in the form of a scaffolding mechanism, which is built into the discussion space to support and aid students in advancing their discussions, clarify the intent of notes, and further understand the content authored by other students. A total of six scaffolds were provided to students in this study, namely, "My theory", "I need to understand", "New information", "This theory cannot explain", "Putting our knowledge together", and "A better theory". The students had the flexibility of using any of these scaffolds or a combination within the same note. In this study, all the analysed notes contained either a singular use of a particular scaffold or no scaffold is used. Figure 9.2 shows a visualisation of scaffold usage that is built into the Knowledge Forum and shown to the students.

Among the six scaffolds, the first three scaffolds ("My theory", "I need to understand", and "New information") are frequently used. These three scaffolds are noticeably straightforward for students to use and can be used as a theme marker to indicate the author's intention of penning the note. For example, "My theory" is often used to state a student's explanation, and "I need to understand" is used to seek information for answering a question. This opinion or query would then be backed up with the use of the "New Information" scaffold, usually in the form of observation, citation, or reference to research.

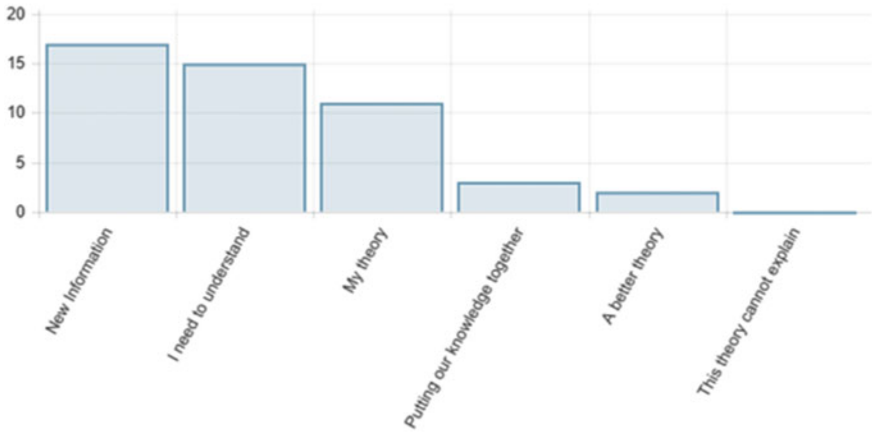

Fig. 9.2 An example of a visualisation shown to students that counts usage of scaffolds

The remaining three scaffolds ("This theory cannot explain", "Putting our knowledge together", and "A better theory") are higher level scaffolds used for evaluating ideas, integrating ideas, or proposing alternative ideas; their usage thus often occur after a basic layer of discourse has been established. For example, various threads of notes can be pulled together into a single train of thought with the "Putting our knowledge together" scaffold, and at times, some students used "A better theory" with "New Information" to back up their new theory. Students also used "This theory cannot explain" scaffold to debate about the limitations of an argument.

In this study, the analysis focused on understanding the author's intent for each note, based on the type and pattern usage of the scaffold in the discourse. The scope is also limited to two scaffolds, namely, "My theory" and "New information", so as to understand the relationship between the use of advancing ideas and providing evidence or backing, and the impact of analytics on knowledge building discourse and the community.

Although the above-mentioned scaffolds are provided to indicate the purpose of a note, customised scaffolds can also be created for particular contexts and learning environments, which students might not have come across or have no prior experience in handling. An example of such a customised scaffold is the "did you know" scaffold, which students can use interesting trivia or knowledge to engage other students to discuss a certain topic. This can lead to further investigations by students and the improvement of ideas to advance communal knowledge.

In this regard, the extent to which scaffolds are created and utilised can be monitored and interpreted as the effort and support that students in the discourse community are providing to support one another in the knowledge building process. Next, the methodology Idea Identification and Analysis (I2A), which is part of the suite of analytic tool found in Knowledge Forum, was developed and used for a more in-depth analysis to relate scaffold use with the interpreted quality of ideas within a discourse.

9.3.3 Idea Identification and Analysis (I2A)

This methodology (Lee et al., 2016) was developed to identify ideas that are promising to the discourse community from discourse analysis. Essentially, the I2A methodology contains methods that assist the analysis of knowledge building discourse, through text-mining and utilising features found within textual discourse to conduct a social network analysis (SNA) using specific network measures, such as Betweenness Centrality (BC). The BC measure is recorded and monitored over the period of discourse, and temporal analysis is conducted on the BC trends to discover patterns that might be representative of promising ideas in notes. Through further investigations, ideas that are promising can be further differentiated and classified, based on the subsequent impact of ideas on a discourse, into promising ideas.

In this chapter, promising ideas refer to ideas that are relevant to the community, can sustain interests of the community, and are deemed worthy of the effort to pursue, with a likely significant impact on the ensuing discourse. The discovery of promising ideas in the discourse, along with their effects on the communal discourse, is then subsequently validated using qualitative content analysis.

9.4 Findings and Discussion

9.4.1 Analysis of the Use of Scaffolds in Knowledge Forum

On the whole, there is a dispersed usage of the six scaffolds throughout the discourse, with a decline nearing the end of the course due to lower discourse activity and possibly discussion "fatigue" as the students were winding down nearer the end of the course for their final assignment. In addition, there was no customisation or creation of newer scaffolds during the entire discourse, representing a missed opportunity to know whether students are satisfied with currently available scaffolds, or are complacent in improving their own understanding.

In the following analysis, the focus of the study is placed on two scaffolds ("My theory" and "New information") that showed significant changes in usage behaviour across the course duration. These two scaffolds are selected to provide insights into scaffold usage behaviours, before and after the presentation of analytics results to the students. This analysis is then used to explain the impact of learning analytics on subsequent scaffold usage and student discourse. For a fairer comparison of usage patterns across the whole course duration, the calculation of scaffold usage is based on the number of scaffolds used per note posted within the specified discourse period, rather than on the absolute number of scaffolds used within the same period of discourse.

Figure 9.3 shows that in the early stages of discourse, there was a large increase in the use of "My theory" scaffold after analytics results were shown to the students, suggesting that students were buoyed by the analytics results to continue voicing

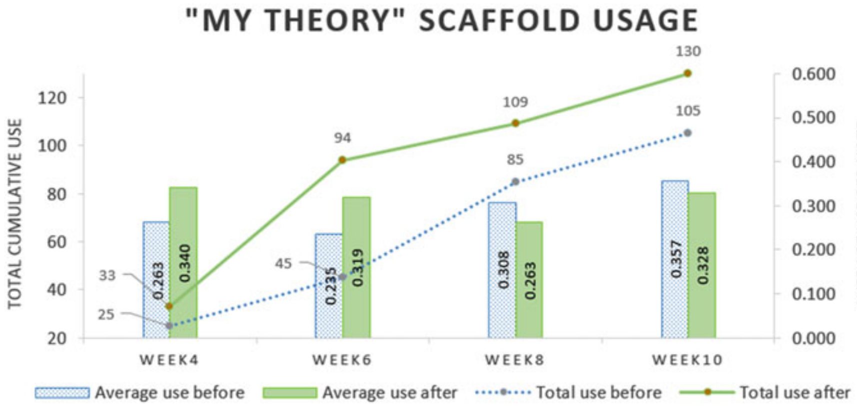

Fig. 9.3 Comparison of average and total cumulative use of "My theory" scaffold, before and after showing analytics results to the students

out their ideas. Analytics results consist of a list of promising ideas identified from the previous week's discourse, showing students that selected contributions to the discourse were recognised by the discourse community and the teaching staff. This attributed to an increasing trend of scaffold usage as students became energised to continue contributing and improving each other's ideas through discourse, in hopes of contributing promising content and ideas to the discourse community. This trend, however, decreased in the second half of the discourse, with the analytics results having a lower impact on how students use the scaffold in their discussions. Students were still using scaffolds, but at a slower rate than in the first half of the discourse.

As students state their claims in the discourse, newer ideas could also be found for evidencing or to back up their claims, especially in a higher education setting. Therefore, an increase in the number of student ideas would have an expectedly similar rise in scaffold usage for evidencing. Surprisingly, Fig. 9.4 shows that there was generally fewer use of the "New information" scaffold after analytics was shown to the students. It is possible that students became more involved in theory-making processes after viewing highlighted promising ideas and content, but were unable to gather newer and appropriate examples or empirical research to back up their theories. This scenario result is highly plausible since an increasing depth of knowledge is required to understand the field of CSCL and knowledge building as the course progresses throughout the weeks and in-depth evidence may no longer be readily accessible and available.

Besides this observation, the impact of analytics results on the use of the "New information" scaffold is more prominent at the later stage of discourse, as shown by a growing gap in usage before and after analytics results were shown. One plausible explanation for the decline in usage of the "New information" scaffold is that some students, upon knowing the presence and source of promising ideas within a community, no longer felt the need to provide additional evidence to prove and substantiate their opinions to fellow coursemates, since the ideas are considered the most

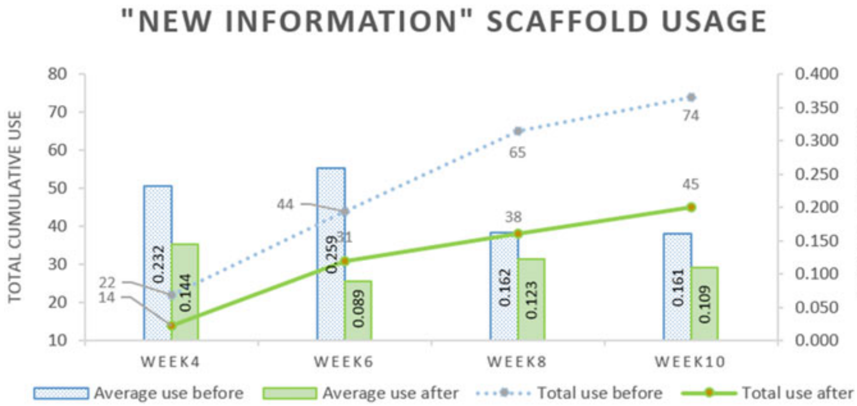

Fig. 9.4 Comparison of average and total cumulative use of "New information" scaffold, before and after showing analytics results to the students

promising direction for discussion. This is exemplified by a note that was written by a student who made reference to the previous week's promising ideas and has experience with KB in classrooms. The student stated "Essence lies in the advancement of knowledge. KB is unlike problem-based learning, as the KB community's objective is understanding rather than deriving solutions to problems (Discourse Unit 801)". This is a statement that implies a level of understanding of KB and communities, but lacks sufficient context and explanation that caused other students who were not as proficient in CSCL and KB to question "How have you implemented KB in your classrooms? Can you give some examples? (Discourse Unit 808)".

Another possible reason to explain the widening gap of usage towards the end of discourse could be the increasing familiarity that students have with the course content and other students, and hence complacency could have set in and students no longer see the need to provide as much evidence as before for their opinions and when conversing with other fellow classmates. Evidencing might no longer be a priority when opinioning and could be found wanting, especially if students were to question the viability of carrying discussions beyond Knowledge Forum, such as whether "the experiencing of 'social' and 'networking' can be transferred to real-life experiences" since "we have been posting and replying each other online, so we officially have dialogues. Do we and will we as classmates talk and socialise outside of Knowledge Forum? (Discourse Unit 654)".

Even though the results suggest showing analytics results to students might not have influenced efforts for evidencing, this effect did not dampen the use of the "New information" scaffold throughout the discourse and still has a consistent rate of use per note. In all, the above observations and data provided a glimpse of how showing of analytics results to students has affected the use of scaffolds to improve students' ideas in knowledge building discourse. To further understand how learning analytics affects the improvement of ideas in the discourse, an Idea Identification and Analysis (I2A) was conducted to identify promising ideas in discourse and determine possible effects that scaffold usage can bring about in discourse.

9.4.2 Relating Scaffold Usage to Promising Ideas in Discourse Using I2A

As described in the methods section, I2A builds a network of notes and keywords from the discourse in this study, based on a bipartite relationship between the students, notes, and keywords. A temporal network analysis was then conducted on the network of notes to obtain a network coefficient, betweenness centrality, for tracing the evolution of selected ideas within a discourse space. Since the sum of the first three scaffolds that support ideation and evidencing ("My theory", "I need to understand", and "New information") experience similar growth as the remaining three scaffolds, the cumulative number of scaffolds over the four cycles of discourse is instead, used as a measure in the following finding. In Fig. 9.5, the number of promising ideas being contributed to the discourse is calculated and compared with the cumulative use of scaffolds throughout the whole discourse.

The results in Fig. 9.5 provided two insights into the relationship between the use of scaffolds and the quality of ideas in knowledge building discourse.

First, the affordance of scaffolds in Knowledge Forum allowed students to give ideas defined roles in processes such as theory refinement and constructive criticism (Scardamalia, 2004). As such, students can then review and revise ideas, and eventually be able to improve ideas into promising ideas that have some form of impact or influence on the community and discourse. Therefore, as shown in Fig. 9.5, when there is an elevated use of scaffolds in discourse over the duration of discourse, the number of promising ideas identified in discourse has also increased likewise.

Second, although scaffold usage increased throughout the discourse, it is doing so at a decreasing rate, as shown in Fig. 9.5. As Scardamalia (2004) describes, the provision of scaffolds in Knowledge Forum is opportunistic rather than mandated, and therefore, this result suggests that in general, students became accustomed to

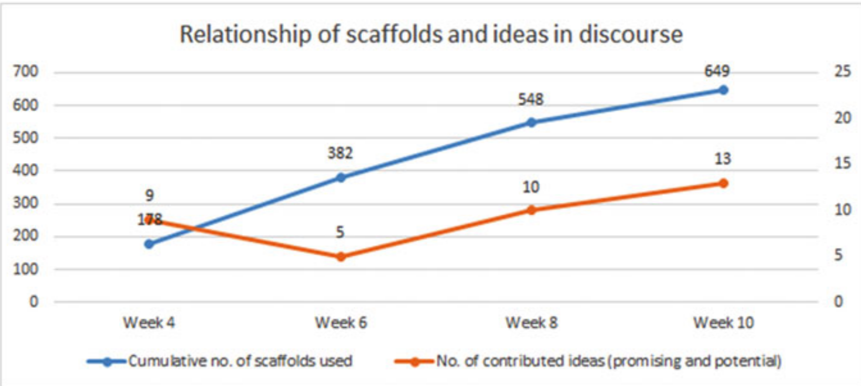

Fig. 9.5 Comparison of cumulative scaffold usage with the respective number of ideas contributed within the cycle

the ability to share, revise, and improve ideas through online discussions, and were able to produce ideas of quality nearing the end of discourse without the assistance of scaffolds.

Although not definitive, the results in this study have shown that the use of scaffolds in knowledge building discourse has impacted students' learning behaviours, as shown by the increased opinioning, evidencing, and quality of ideas throughout the discourse. To properly assess scaffold use and idea quality in discourse, it can be concluded that the use of learning analytics is essential as part of an analytical framework that is conceivable and feasible for implementation in the educational setting, with authentic case studies and results to convince users of the plausible benefits of learning analytics in discourse analysis.

9.5 Concerns, Limitations, and Future Directions

The above analyses have shown some of the insights that can be obtained from new technologies, algorithms, and the use of data analytics in the current education system. There, however, remain several pertinent research and implementation issues when learning analytics are involved. These issues, alongside suggestions for future research that builds on learning analytics mentioned in this chapter, are discussed in this section.

9.5.1 Opportune Timing and Suitable Environment for Learning Analytics

The results from the analyses in this chapter have shown that the introduction of learning analytics tends to have a greater impact on the discourse community during the initial stages of discourse and subsequently tapering as the stamina for discourse wore out. The choice of learning analytics was appropriate for the study's purpose, which is to discover promising ideas in discourse for sustaining idea improvement and encourage deeper discussion. Students were able to identify and understand key challenges, improve and build on ideas, and advance collective knowledge.

As such, there is a need for teaching staff to strategise possible ways of conducting the knowledge building sessions and balance the usage of learning analytics in discourse according to individual and communal goals. For example, learning analytics can be implemented post-lesson without affecting the students, but this might only benefit the teaching staff and subsequent cycles of students where the impact might not be significant and conspicuous. If the analytics were implemented during discourse and results were consistently offered throughout the course as shown in this study, the impact on students might fade over time and produce negligible benefits from greater efforts in the implementation or sustenance of analytics over a longer period of discourse.

Hence, depending on the learning goals of lessons and the students that would be involved in any discourse analysis, it would be beneficial to state the goals of discourse upfront and in this study, further assure students that the gain of information would be far more treasured when shared among the community to advance communal knowledge. By fostering a safe learning environment, students would then be able to share and build on knowledge in a judgment-free zone where every idea is deemed improvable and contributes to a communal effort for advancing knowledge.

9.5.2 Adoption and Scaling in Educational Institutes

The phrase "the only constant is change" rings consistently true within the current dynamic field of analytics in education, which has been filled with growing technological changes that try to usurp long-established practices of teaching and learning in educational institutes. However, as much as learning analytics have shown potential benefits in enhancing teaching and learning efficacy, barriers to the adoption of learning analytics continue to exist in both psychological forms and long-term costs that prevent feasible implementation at scale within educational institutes.

Prevalent resistance to change still remain within some teachers who are not convinced of the benefits of learning analytics, especially when the implementation of learning analytics requires considerable effort, skills and commitments from the teachers. An example would be the immense effort required from multiple parties to digitise the entire syllabus and content of a course to be placed on a learning management system (LMS) in order to install digital monitoring mechanisms for the analysis and grading of short student essays or discourse. Instructors might feel there are insignificant benefits towards teaching and learning, especially if the original intention of such assessment was formative or peer assessed.

Other long-term costs also exist, especially in terms of manpower and expertise required to construct and maintain a feasible information technology (IT) infrastructure and database to properly manage collected data and analytical software. These challenges, although not currently prevalent and conspicuous in education settings, are part of practical problems that have surfaced within larger corporations that have delved into big data and analytics. Such bigger problems can surface within educational institutes in the future if they are not prepared to handle potential issues with an appropriate framework or possess sufficient manpower.

9.5.3 Ethics in Learning Analytics

Although learning analytics can assist the understanding, visualisation, and optimization of learning within online environments, such as the online discourse as discussed in this chapter, there remain concerns regarding the ethical use and management of personal data.

Concerns regarding ethical data ownership and sharing (Slade & Prinsloo, 2013) are prevalent in the current discourse on big data and analytics. Although ethical issues may vary among different countries and cultures, most studies share common goals in ensuring that practices conform to codes of practice (e.g. Sclater, 2016) and reduce issues of misuse in the handling of data and collection processes. However, more could still be done by educational institutes in ensuring there are proper tracking and monitoring of ethics for collection, analysis, reporting, and accountability of data. There is always room for these processes to be further strengthened, as pointed out by Siemens (2013), through proper governance and improvements to current legal systems.

9.5.4 Future Directions

Learning analytics have thus far been utilised prevalently for information, personalisation, and prediction purposes, with emerging interests in the educational setting, as shown in this study, to benefit teachers and students in identifying knowledge gaps and possible areas for improvement. It is currently possible to develop profiling of learners through the fusion of emotional aspects and learning analytics (Suero Montero & Suhonen, 2014), and there are also other new affordances from novel technologies, such as the Internet of Things (IoT) (Gubbi, Buyya, Marusic, & Palaniswami, 2013), which can be creatively integrated with learning analytics to encourage greater interactivity between learners.

Although there are leading analytical tools and algorithms that proclaim to be able to provide solutions to complex problems, however, the implementation of interventions is still heavily dependent on the teaching staff. Learning analytics in online knowledge building discourse is, after all, a significant development and key step in aiding teachers to analyse discourse, and to improve teaching and learning within online discourse environments. Nevertheless, much still needs to be done in order for learning analytics to be fully integrated into the current education system and for meta-learning to occur. For students, they would need to be in a state of being aware of and take control of one's own learning (Biggs, 1985); and for teachers, even though learning analytics might be a great assistance in classrooms, they would still need to have the prerogative to make meaning from the visualisations and insights, so as to decide on relevant and meaningful interventions for the students.

9.6 Conclusion

This chapter details the investigation of the use of learning analytics and its effects in an online knowledge building discourse. Scaffolds were used as thinking cues and helped students to improve their ideas through discourse. Learning analytics was utilised to analyse scaffold usage patterns and to identify promising ideas in a discourse, which helped students in understanding the key challenges and efforts to sustain idea improvement in a knowledge building discourse. The effects of analytics results on the community, existential limitations, concerns, and future directions are discussed. Overall, the results of the study suggest that students benefited from the usage of learning analytics with discourse analysis in the practice of knowledge building.

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Chapter 10
Features Identification and Classification of Discussion Threads in Coursera MOOC Forums

Ean Teng Khor

Abstract In this chapter, the discussion threads of six MOOCs courses offered from August 2013 to April 2014 via the Coursera forums were analysed. The purpose of this study is to identify important features that may have an impact on supervised classification analysis in predicting discussion threads that require instructors' intervention. This study worked on data from the anonymised Coursera MOOC forums with 45,303 threads to gain an insight into the forums. The important features related to thread structures, social network, and popularity are identified using Univariate Feature Selection. Classification analyses using neural networks, decision trees, and naïve Bayes algorithms were applied to generate the predictive models. The results show that the developed predictive model is performing well, and the decision trees algorithm outperformed other algorithms with excellent performance measures based on the level of accuracy, precision, recall, and f-measure.

Keywords Massive open online courses · Features identification · Supervised classification · Machine learning algorithms · Predictive modelling

10.1 Introduction

Massive Open Online Courses (MOOCs) have gained global attention within educational communities (Tseng, Tsao, Yu, Chan, & Lai, 2016), and the development of MOOCs has been recognised as one of the remarkable innovations in the education sector (Jacoby, 2014). According to Klüsener and Fortenbacher (2015), there is an increasing interest in MOOCs over the past few years and it has the potential to scale up university education.

In general, MOOCs are known to provide interesting learning experiences through video lessons, learning materials, quizzes and many MOOCs allow anyone in the world to study a course online. Many of these courses are free and open for anyone, a feature that usually attracts a huge number of learners in a short time. For instance, Xu and Yang (2016) reported that the total number of registered MOOCs learners

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has exceeded 14 million and the number is increasing each second in Coursera, a MOOC platform.

One of the features that attract researchers to MOOCs is that activities of learners are recorded in detail, and they present great potential for big data characterization and insightful analytics. This study focuses on data related to online discussion forums in MOOCs. Unlike traditional modes of delivery, an online discussion forum is the main platform for interaction between instructors and students in MOOCs (Chaturvedi, Goldwasser, & Daumé III, 2014). There are a number of potential benefits for the MOOC forums. First, they support instructor–student interactions. Students may post any course-related questions when pursuing the solution for a particular problem. Second, timely feedback on the discussion forum by instructors could enhance learners' engagement in MOOCs. Santos, Klerkx, Duval, Gago, and Rodríguez (2014) found that students who participated actively in the forum discussion would have a better chance of passing the course.

While there are many potential benefits of MOOC forums, there is also an immense challenge for the instructor: moderating the forum discussions and monitoring students' interactions. It is time-consuming for the instructor to follow all discussing threads manually due to the extremely high ratio of learners to an instructor (Chaturvedi et al., 2014). According to Chaturvedi et al. (2014), a large number of threads on MOOC discussion forum could be generated even during a short duration of a course owing to the huge class size; there is thus a need for automatic curation of the discussions for the instructors. This study aims to address this problem by identifying discussion threads that require instructors' intervention. A forum consists of one or more discussion topics, while a discussion thread is referred to each post within the discussion topic.

10.2 Building on Extant Works

The aim of this study is to identify important features of discussion threads in MOOC forums and develop a practical predictive model capable of forecasting discussion threads that require instructors' intervention. This model is built based on the identified thread structure features (e.g. number of tags and number of words), social network features (e.g. user *ID*) and popularity features (e.g. number of views and votes). According to Shahiri, Husain, and Rashid (2015), data mining methods such as regression, classification and categorisation can be used for predictive modelling and among them, classification is the most popular technique for prediction, hence, the choice of classification techniques in this study to develop the predictive model.

Classification is a supervised learning method where targets are predefined (Gupta, Kumar, & Sharma, 2011). It classifies data into predefined target and builds a classifier based on the training set. The classifier is then used to forecast new cases. It involves two steps: a model is first built from the data tuples of the training set and the accuracy of the model is then evaluated using the test set (Bansode, 2016). Classification analysis predicts the value of class labels based on the values of other predicting attributes (Romero, Ventura, Espejo, & Hervás, 2008). There are several algorithms under classification analysis that can be used to generate predictive modelling. This study used neural networks, decision trees, and naïve Bayes, which are widely used algorithms for classification analysis.

Neural networks algorithm is one of the popular classification methods used for prediction. The algorithm is able to identify all possible connections among independent variables (Gray, McGuinness, & Owende, 2014). A complete detection can also be done by the algorithm for a complex non-linear relationship between independent variables and dependent variables (Arsad & Buniyamin, 2013). There are three layers in a neural network model, namely, the input layer, hidden layer and output layer. The input layer reads input from a user program, while the output layer writes output to the user program (Amrieh, Hamtini, & Aljarah, 2015). The hidden layer is connected to *neurons*, which refer to the interconnected processing elements that work together to yield an output function (Romero et al., 2008).

Decision trees algorithm is a widely used classification method due to its comprehensibility and simplicity in discovering large or small data structures (Shahiri et al., 2015). A set of IF-THEN rules can be converted into a decision tree, and it is easily understood (Romero et al., 2008). A decision tree is a predictive model to classify an instance by following a path of satisfied conditions from the root until it reaches an end node (Romero et al., 2008). It is in tree-shaped structures representing sets of a decision and the decision generates rules for the dataset classification (Baradwaj & Pal, 2012).

Naïve Bayes algorithm is another popular technique used in classification. The algorithm is easy to understand and is able to predict a class using probability. It follows the principle of statistical independence of each feature and gives probabilistic outputs of classification (Brooks & Thompson, 2017). The classifier calculates the probabilities of attributes values based on the training data, and the probabilities are then be used to classified new entities (Amrieh et al., 2015).

Researchers have analysed MOOCs in various ways. Rossi and Gnawali (2014) analysed MOOCs in Coursera and used classification for discussion threads in forums; they examined the temporal and structure dynamics of the discussion threads and user votes. Brinton et al. (2014) analysed Coursera MOOCs and proposed a classification technique to filter out discussions with small talk. They studied the decline rates of both participants and posts in the discussion forum. Xu and Yang (2016) classified students into three different groups by their motivation based on their activity in MOOCs. The students' course grade was then predicted based on student activity features through classification analysis. Wen, Yang, and Rose (2014) predicted which students were more likely to withdraw by performing sentiment classification analysis on the discussion threads of three Coursera MOOCs courses (one social science course, one literature course, and one programming course).

While there are many existing studies about the application of classification techniques on MOOCs, there are limited studies of the use of classification methods in MOOCs forum, especially in the case of identifying discussion threads that require instructors' intervention.

10.3 Research Methods

In this chapter, the dataset collected from Coursera MOOC forums was used for analysis. It is an open-source dataset and the original source of the dataset is from Rossi and Gnawali (2014). Six MOOCs courses offered in Coursera were selected, including (i) Big Data in Education, (ii) Linear and Integer Programming, (iii) Gamification, (iv) Online Games: Literature, New Media and Narrative, (v) Climate Literacy: Navigating Climate Change Conversations and (vi) Global Warming: The Science of Climate Change.

Table 10.1 summarises the course information including the course ID, the number of threads, threads with instructor's posts and threads with student's posts. There were 45,303 discussion threads used in this study. The discussion threads consisted of posts related to discussions, assignments, lectures, video lectures, study groups, quizzes and homework. Out of the 45,303 discussion threads, 2,209 are threads with the instructor's post and the remaining are threads with student's posts.

Figure 10.1 illustrates the main research procedure in this study. Data preprocessing includes data cleaning, data transformation and feature selection. Data cleaning was conducted to reduce the noise, outlier and missing values and data transformation was carried out to convert data from one format to another appropriate format ready to be processed by different classification algorithms. Feature selection was performed to reduce the number of attributes that are irrelevant or

Table 10.1 Summary of course information

Coursera course	Course ID	Number of threads	Threads with instructor's post	Threads with student's post
Big data in education	bigdata-edu-001	3,802	435	3,367
Linear and integer programming	linearprogramming-001	4,511	1,186	3,325
Gamification	gamification-003	14,329	36	14,293
Online games: literature, new media and narrative	onlinegames-001	9,444	364	9,080
Climate literacy: navigating climate change conversations	climateliteracy-002	8,040	29	8,011
Global warming: the science of climate change	globalwarming-001	5,177	159	5,018
Total		45,303	2,209	43,094

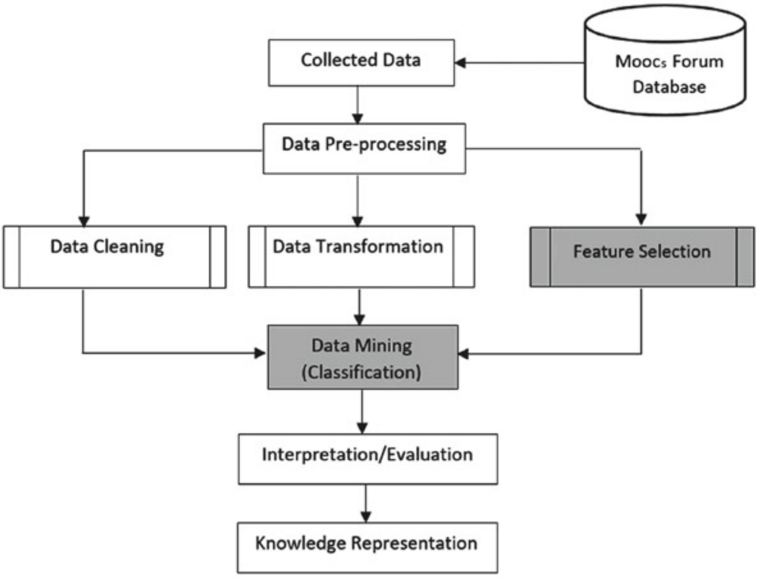

Fig. 10.1 Main research steps

redundant. Feature selection algorithms are applied to evaluate the importance of features by selecting the most relevant features such as variables, predictors by using feature weighting or feature ranking methods. After feature selection, the data mining process was carried out. A total of 45,303 data points were created in the study. A predictive model was then built by using three different classification analyses: neural networks, decision trees and naïve Bayes.

A model, in general, uses a set of mathematical formulas to explain the quantitative relationship between independent variables (inputs) and a dependent variable (output) (Huang & Fang, 2013). In this study, the inputs of the model include (1) number of tags associated to the sub-forum title, (2) number of posted words, (3) user ID, (4) number of views for the thread and (5) total number of the votes received by post. The output of the models is user types (*instructor or student*). Table 10.2

Table 10.2 Coursera MOOC forum dataset features

Category	Feature	Description	Data type
Thread structures	num_tags	Number of tags associated with the forum title	Numeric
	num_words	Number of posted words	Numeric
Social network	user_id	User ID (hashed version of original Coursera user ID)	Numeric
Popularity	num_views	Number of views for the thread	Numeric
	votes	Total number of the votes received by the post	Numeric

shows a set of features that were used for the classification analysis of the discussion threads. Next, the developed model is validated to assess whether it predicts accurately. In this study, 10-fold cross-validation was used to validate the accuracy of the model. Random sub-sampling cross-validation was performed to categorise the dataset into training and testing category. It then averages the result after running a model multiple times in a randomised environment (Smith, Lange, & Huston, 2012). In short, the model was tested using random sub-sampling cross-validation with 10 repetitions. The data mining process was then followed by the interpretation and evaluation of patterns and results. Lastly, knowledge representation was generated. The generated predictive model is able to identify the discussion threads that require instructors' intervention.

10.3.1 Feature Selection

With the proliferation of large-scale courses such as MOOCs, the researchers faced the challenge of processing a massive amount of learners' data (Yuan & Powell, 2013). The application of data mining and machine learning algorithms on education datasets often presents issues of high dimensionality due to an increase of class size with a large number of features.

The exponential growth of discussion forum data sources has prompted the use of feature selection method (Univariate Feature Selection) to identify features related to thread structures, social network, and popularity to enhance accuracies in predicting forums that need instructors' intervention. Feature selection is often used as a pre-processing step before the features are fed into the algorithms. Feature selection research works have shown effective results in addressing the problems of data with high dimensionality (Li et al., 2017), improving the efficiency of training process (Xu & Rockmore, 2012), and improving computational efficiency by using a selection of subset of relevant features (Guyon & Elisseeff, 2003) that are useful to building good prediction system.

In educational data mining, Mantecon, Hadi Abdi Ghavidel, Jovanovic, and McDonald (2018) applied feature selection for comparison of features to be used for automatic labelling of student answers to open-ended questions for a first-year health sciences course. The authors explored the use of vector space models (VSMs) to examine and compare the predictive power of different text features derived from students' answers and used in combination with classification algorithms to classify correct and incorrect answers.

To build a responsive intelligent tutoring system, McDonald, Knott, Zeng, and Cohen (2011) evaluated the features derived from the student responses of dialogue corpus such as bag of words, word length, first-word, stemming and stopwords using naïve Bayes classifier to develop high-quality tutorial dialogue system to provide timely and individualised feedback to undergraduate students. The classifiers were evaluated with different feature sets until the highest accuracy in the test results was achieved. Once the best features were identified, the training of dialogue contribution classifier with a larger number of samples was carried out to improve the accuracy.

In this study, the use of feature selection method aims to increase accuracy scores and perform dimensionality reduction (i.e. reducing the variables from high-dimensional datasets). Univariate feature selection selects the best features based on univariate statistical tests and provides the highest score which has the strongest relationship with the output variable (i.e. class, category or label). Univariate feature selection with *chi-squared* and *f-regression* was used in this study to rank the MOOCs discussion forum features according to the significance of the regression parameter and the features correlation with the target prediction (Prediction class 1: Posts that involved instructors, Prediction class 2: Post without instructors) to select three of the best features from the MOOCs dataset.

10.3.2 Evaluation of the Classification Model

In this study, the performance of the developed model was measured using a confusion matrix. A confusion matrix (Table 10.3) consists of information on actual and predicted classifications (Singh & Verma, 2014), and it illustrates the accuracy of the solution to the classification problem (Patil & Sherekar, 2013). True Positive (TP) refers to the cases when the predicted class is positive and the actual class is also positive. False Positive (FP) refers to the cases when the predicted class is positive but the actual class is negative. True Negative (TN) refers to the cases when the predicted class and the actual class are both negative. False Negative (FN) refers to the cases when the predicted class is negative but the actual class is positive (McBeth, 2017).

Besides the confusion matrix, the four common evaluation measures—accuracy, precision, recall and f-measure—were also be used to evaluate the quality of the developed model. According to Abubakar and Ahmad (2017), the overall performance of a model does not depend only on the result of accuracy but other evaluation metrics like precision, recall and f-measure. They are vital to assessing the suitability of a model in terms of class prediction. The four measures (Chen, Kuo, & Merkel, 2004; Powers, 2011) were calculated using a confusion matrix based on the Eqs. (10.1), (10.2), (10.3) and (10.4) as stated in Table 10.3.

Table 10.3 Confusion matrix (Böck, 2016)

		Predicted class	
		Positive	Negative
Actual class	Positive	True positive (TP)	False negative (FN)
	Negative	False positive (FP)	True negative (TN)

Accuracy is the ratio of the correctly predicted instances to the total number of predictions made. A high value of accuracy indicates a large number of correctly predicted instances. Precision is the proportion of the correctly predicted instances from the total number of correctly predicted instances and wrongly predicted instances. A high value of precision indicates a small number of FP. Recall is the proportion of correctly predicted cases from the total number of correctly predicted instances and wrongly predicted instances. A high value of recall indicates a small number of FN. F-measure describes the balance between precision and recall. The score of an F-measure weighted the average of precision and recall (McBeth, 2017). The measure is more useful than accuracy for the case of uneven class distribution.

$$\text{Accuracy} = \frac{TP + TN}{TP + FN + FP + TN} \tag{10.1}$$

$$\text{Precision} = \frac{TP}{TP + FP} \tag{10.2}$$

$$\text{Recall} = \frac{TP}{TP + FN} \tag{10.3}$$

$$\text{F-measure} = 2\frac{\text{Precision} * \text{Recall}}{\text{Precision} + \text{Recall}} \tag{10.4}$$

10.4 Analysis and Results

Table 10.4 shows the ranking of the two scoring functions (*chi-squared* and *f-regression*) used in the univariate feature selection procedure for Big Data in Education. These features are based on aggregated data combined from the course post, course threads of Coursera MOOC forums by Rossi and Gnawali (2014). The prediction scores (in exponential notation) for each of the variables are shown in Tables 10.4, 10.5, 10.6, 10.7, 10.8 and 10.9 (Dark grey—1st rank, Medium grey—2nd rank, Light grey—3rd rank). The ranks are useful for the identification of important features for instructors' intervention prediction. Three highest performing features are indicated in the tables below which exhibits the highest *chi-squared* and *f-regression* score function.

Table 10.4 Feature rankings of big data in education course (bigdata-edu-001)

Feature selection (score functions)	num_tags	num_views	num_words	votes	user_id
chi-squared	1.3503e−1	3.7066e+4	2.957e+3	4.6055	2.6909e+11
f-regression	6.2885e-2	7.8146e+1	2.8077e+1	6.7667e−1	2.1076e+2

Table 10.5 Feature rankings of linear and integer programming course (linearprogramming-001)

Feature selection (score functions)	num_tags	num_views	num_words	votes	user_id
chi-squared	9.9936e − 1	5.0648e+4	2.3817e+5	7.1648e+4	1.8621e+12
f-regression	5.5493e − 1	1.1808e+2	4.0175e+2	4.1605e+2	1.8364e+3

Table 10.6 Feature rankings of gamifications course (gamification-003)

Feature selection (score functions)	num_tags	num_views	num_words	votes	user_id
chi-squared	5.1556e+1	2.4271e+4	6.1929e+1	1.3204e+3	1.1441e+11
f-regression	3.5078	5.1736	0.5757	129.8700	67.4573

Table 10.7 Feature rankings of online games: literature, new media and narrative course (onlinegames-001)

Feature selection (score functions)	num_tags	num_views	num_words	votes	user_id
chi-squared	3.5686	2.1485e+3	9.814e+3	2.106e+2	1.6925e+12
f-regression	1.2864	4.0335	40.5988	48.1786	1104.3242

Table 10.8 Feature rankings of climate literacy: navigating climate change conversations course (climateliteracy-002)

Feature selection (score functions)	num_tags	num_views	num_words	votes	user_id
chi-squared	1.3611e+1	1.6836e+4	4.4335 e+2	1.2579e+1	6.5137e+9
f-regression	5.2737	7.7544	2.5901	6.5707	3.8269

As observed from Table 10.4, *user_id*, *num_views* and *num_words* are the three features that have the strongest relationship with the output variable. In the Linear and Integer Programming course, Table 10.5 shows that *user_id*, *votes* and *num_words* are important features ranked by both score functions.

Table 10.9 Feature rankings of global warming: the science of climate change course (globalwarming-001)

Feature selection (score functions)	num_tags	num_views	num_words	votes	user_id
chi-squared	1.1568e+1	1.3556e+4	1.3448e+3	6.9439e+1	1.1047 e+11
f-regression	7.0914	24.7083	6.8018	21.1165	57.1508

Table 10.10 Classification analysis with evaluation measures

Classifier	Accuracy (%)	Class	Precision	Recall	F-measure
Neural networks	96.9428	Instructor	0.789	0.509	0.619
		Student	0.975	0.993	0.984
		Weighted average	0.966	0.969	0.966
Decision trees	99.9845	Instructor	0.997	1.000	0.998
		Student	1.000	1.000	1.000
		Weighted average	1.000	1.000	1.000
Naïve Bayes	42.8603	Instructor	0.069	0.855	0.127
		Student	0.982	0.407	0.575
		Weighted average	0.938	0.429	0.553

Table 10.6 shows the feature rankings for Gamifications course. The relevant features, *user_id*, *votes* and *num_views* were obtained.

In Table 10.7, the *chi-squared* score function shows that *user_id*, *num_words* and *num_views* are the well-performed features. The *f-regression* score function indicated that *user_id*, *votes*, and *num_words* are the selected features for Online Games: Literature, New Media and Narrative course. Tables 10.8 and 10.9 exhibit dissimilarity of features selected based on both score functions.

Table 10.10 illustrates the analysis result of three classification algorithms based on evaluation measures. The results of the neural networks, decision trees and naïve Bayes in predicting instructor's intervention are compared. The overall performance of all classifiers is illustrated in terms of accuracy, precision, recall and f-measure.

Decision trees classier outperformed the other classifiers with an accuracy of 99.98% followed by the neural networks classifier with 96.94% and naïve Bayes classifier with 42.86% (Fig. 10.2). In the case of precision, recall and f-measure, decision trees classifier also performs better than the other two classifiers (Fig. 10.3).

Table 10.11 presents the results of the confusion matrix with the decision trees algorithm. It illustrates the prediction results of decision trees classifier. For the case of the instructor, all 2,209 cases are classified as "instructor". Hence, the TP rate and the FP rate of the class instructor are found to be 1 and 0, respectively. For the case of the student, 43,087 out of 43,094 cases are classified correctly as "student". The reported TP rate is 1, and the FP rate is 0. Table 10.12 shows the class-wise accuracy with the decision trees algorithm.

10.5 Conclusion

The classification techniques with different data mining measurements were applied to the dataset. The data were pre-processed into a suitable format for the data mining process. A 10-fold cross-validation was used to randomly divide the dataset into ten

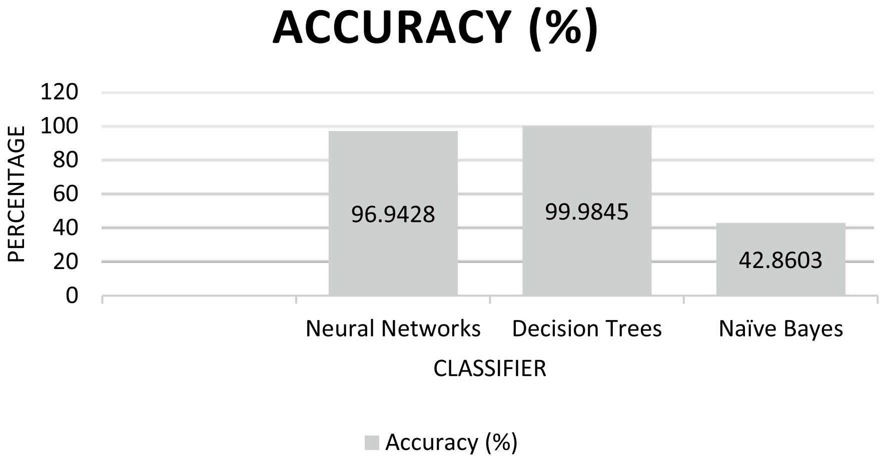

Fig. 10.2 Evaluation of classifiers (Level of Accuracy)

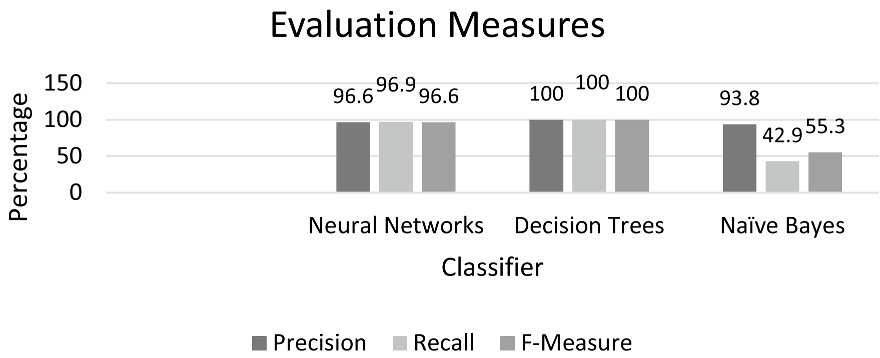

Fig. 10.3 Evaluation of classifiers (Precision, Recall and F-Measure)

Table 10.11 Confusion matrix with decision trees algorithm

		Predicted class	
		Instructor	Student
Actual class	Instructor	2,209	0
	Student	7	43,087

Table 10.12 Class-wise accuracy with decision trees algorithm

Class label	True positive (TP) rate	False positive (FP) rate
Instructor	1.000	0.000
Student	1.000	0.000

subsets where 9 of the 10 subsets were combined to form the training set and the remaining one was used as the test set.

The important features were selected using univariate feature selection. The classifiers, including neural networks, decision trees and naïve Bayes, were used to evaluate the impact of the selected features in predicting discussions that require instructors' intervention. Apparently, features such as thread structures (*num_tags*, *num_words*), social network (*user_id*) and popularity (*num_views*, *votes*) are significant, and they improve the results of the classification analysis.

The performance of different classification algorithms is evaluated based on the confusion matrix and the four common evaluation measures (accuracy, precision, recall and f-measures). The accuracy achieved with the dataset appears to be appealing, which is more than 90% for the two classifiers. The class precision and class recall for both class labels are encouraging too. The experiment conducted revealed that decision trees classifier outperformed the other two classifiers with an overall correct classification rate of 99.98%.

This study concludes the potential use of the decision trees classification model in predicting discussion that requires instructors' intervention. The developed predictive model has high accuracy and able to identify the discussion threads that require instructors' intervention.

The model generated in this study can be applied to help MOOC instructors. The model helps to classify the discussion threads so that the instructors do not need to follow all discussing threads manually. Consequently, the instructors are able to take a proactive measure based on the results of the predictive model. The just-in-time intervention can be provided, and the necessary feedback can be given to the students in a more efficient way. This could enhance the overall teaching and learning process and promote student success.

In the future, ensemble methods like bagging and boosting can be studied to improve the modelling process and obtain better predictive performance. Bagging creates a composite classifier and combines the outputs of the learned classifier into a single prediction. On the other hand, in boosting, each classifier is influenced by the performance of the previous classifier. The output of a learned classifier is used in the creating of the next prediction. The current study classified only the post of the discussion forum; the classification for the word of threads can be performed in future studies. The current experiment can also be carried out with different classification algorithms such as k-nearest neighbours and support vector machines to predict instructors' intervention in discussion threads.

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Part IV
Learning Environments

Chapter 11
Exploring the Relationships of Factor Measures in Blended Learning Environments

Betsy Ng, Seng Chee Tan, Choon Lang Quek, Peter Looker, and Jaime Koh

Abstract Based on Bigg's 3Ps (Presage, Process and Product) model, this study investigated the relationships of factors in the context of blended instructions that integrated online components with face-to-face instructions. The presage factors include student preferences, course design, instructor presence, student presence and cognitive presence; the process factor measures student approaches to learning; the product factors include student outcomes and course grade. There were 109 undergraduates who attended blended learning courses in a university in Singapore who responded to the online questionnaire at the end of a semester. Structural equation modelling pertinent to learner preferences (i.e. active versus passive); course design; instructor, student, and cognitive presence; and student outcomes showed a marginal fit to the data, indicating that the presage-process-product format could likely act in concert. Contextual differences and the instructor's presence may also influence student approaches to studying. Implications and limitations of this study are discussed.

Keywords Learning environments · 3Ps model · Approaches to learning · Presence · Outcomes

11.1 Introduction

This study sought to examine students' perceptions of blended learning environments and their approaches to learning. Learning environments may influence the ways that students learn, which, in turn, may affect their learning outcomes such as skills gained and academic performance. Guided by Biggs' framework known as the 3Ps model (i.e. presage, process and product), this study developed an instrument to evaluate students' perceptions of blended learning environment, approaches and outcomes.

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Factor analyses were used to validate the instrument, known as the 3Ps Questionnaire (3PsQ). With this instrument, we examined university students' perceptions towards blended learning, as well as the presage-process-product relationships. The findings of this study yielded evidence for the relationships among students' perceived instructor, student and cognitive presences, approaches to learning, as well as learning outcomes.

Based on our knowledge, there is no local study that explores the relationships of student learning outcomes in blended learning environments. The development of the 3PsQ could contribute to both educational research and methodologies. The 3PsQ may provide insights into university students' approaches to learning in blended learning environments since most universities offer blended learning courses. Furthermore, this study may be used as a reference case within Singapore for future investigations and provides a good lead in evaluating the quality of learning and teaching at the university level.

11.2 Key Constructs in This Study

This section explains the key constructs in this study and how findings from relevant studies help to shape the present study.

11.2.1 Learning Environment

Learning environments may impact students' ways of learning and the quality of the desired outcomes. Specifically, students' perception of an academic learning environment could influence their approach to learning and academic performance (Lizzio, Wilson, & Simons, 2002). However, there is some inconsistency in the measurement models of learning environments. For instance, Meyer and Parsons (1989) used the Course Perceptions Questionnaire (CPQ), and they did not find any relationship between the learning environment and students' approaches to studying. With this finding, they concluded that the CPQ is not adequate for measuring the relationships between contextual factors and approaches to studying at an individual level. Other related research reported a negative association between workload and surface approach (Trigwell & Prosser 1991), but a positive association between good teaching and a deep approach to learning (Lizzio et al., 2002). There are other studies that used the Course Evaluation Questionnaire (CEQ) to evaluate the presage factor of a teaching context (e.g. Fryer, Ginns, & Walker, 2014; Sun & Richardson, 2016). Their findings showed positive relationships between students' perceived classroom environments and students' preferences towards learning. It is likely that students' perceptions of the type of learning environment influence how they learn and the variations in their approaches to learning.

11.2.2 Blended Learning

Blended learning, in simple terms, is commonly regarded as the integration of face-to-face teaching with online components and activities, sometimes called e-learning (Garrison & Kanuka, 2004). The application of blended learning courses is gaining traction in universities to complement traditional teaching methods. For courses that have high student enrolments, blended learning could extend the presentation of information and concepts to large class sizes, thus provides an efficient means for learning basic concepts. The online components allow students to grasp the fundamental knowledge of the course at their own pace, and they can revisit the online materials multiple times. Students can learn independently or together with their friends elsewhere, which is an advantage over instructions through traditional classrooms or lecture theatres. The face-to-face instructions could complement online learning with guidance from the instructors, for example, in problem-solving or in offering a more in-depth explanation of difficult concepts and principles.

Asarta and Schmidt (2017) compared student's performance between blended and traditional courses, taking into consideration the students' prior academic achievement. They found significant differences in student performance for students achieving different grade point averages. For low grade point average group, the performance was higher in the traditional version of the course; for those with high point averages, the performance was higher in the blended version. Another comparison study on the effects of blended learning and traditional face-to-face learning environments on students' achievement was conducted by Olelewe and Agomuo (2016). The result from the study indicated that a blended learning approach was more effective than the traditional face-to-face method with respect to improving students' achievement in QBASIC programming. Al-Qahtani and Higgins (2013) studied three modes of instructions—traditional face-to-face classroom learning, blended learning and e-learning—and compared their impact on students from Saudi Arabia. Their results showed that there is a statistically significant increase in the achievement of students who used blended learning when compared to the achievement of students who used e-learning only. The significant impact of blended learning on academic essay writing, however, was not repeated in another study by Ferriman (2013) on college students in Thailand. The essay writing was assessed with three dependent variables, namely, number of references, word count and essay scores. The study reported no significant difference between the experimental and control groups on any of the three dependent variables; the experimental group performed just as well as the control group.

Self-control and self-regulated learning of university students in a blended course was studied by Zhu, Au, and Yates (2016). Their results showed that participants who reported higher levels of self-control capability and self-regulated learning achieved better learning outcomes. Another study on blended learning conducted amongst

Ugandan university students (Kintu & Zhu, 2016) found that learner attitudes, management of workload and learner interactions were significant factors for learner satisfaction, while management of workload and interactions were significant factors for knowledge construction in blended learning.

In terms of student perceptions and achievement in a blended learning environment, a study by Owston, York, and Murtha (2013) on 1147 students in a Canadian university found that the highest achievers were most satisfied with their blended course and preferred the blended format over fully traditional face-to-face or online learning. Students from a Spain university also expressed greater satisfaction in blended learning courses than traditional face-to-face learning approaches (Martínez-Caro & Campuzano-Bolarín, 2011). Another study investigated the motivation level in terms of gender and revealed that male students were more satisfied with blended learning than female students (Naaj, Nachouki, & Ankit, 2012).

From the above review of extant research studies, it is apparent that contradictory findings exist. Moreover, there is still limited research in examining university students' perceptions of blended learning environments and their relationships with the approaches to learning and outcomes.

11.2.3 3Ps Model

Biggs (1989) presented a conceptual learning model that took into consideration three variables to form a stable yet interactive system. Biggs' (1989) 3Ps model includes presage factors, process factors and product factors.

Presage factors refer to those that occur or exist before learning takes place. These include lasting personal characteristics (such as the learner's earlier awareness, understanding, ability and disposition) that are imbued within learners and brought into the learning context (for instance, pedagogy, amount of work and programme structure). Ramsden (1991) highlighted that the model can be applied in an everyday situation whereby perceptions of learning environments and situations may guide the learning approaches and outcomes. There are two components in the presage phase, namely, student learning and teaching context. Presage in student learning refers to the student context which includes student characteristics (i.e. active or passive learner preference), prior knowledge abilities, the concept of learning and orientation to learning such as language competence or expectations concerning achievement (Biggs, 1991). Passive learner preference is defined as the orientation toward receiving information from the instructional materials without meaningful engagement, whereas active learners tend to engage cognitively and involve in meaningful learning. The second key component in presage is the teaching context. Teaching context includes contextual or classroom factors such as structure and learning climate; instructional methods such as teaching and assessment; and institutional rules surrounding learning. Within a teaching context, it is important to pay attention to three key elements (i.e. instructor presence, student presence and cognitive presence) so as to achieve quality in student learning. Instructor presence refers to the design, facilitation and direct instruction of the instructor (Arbaugh et al., 2008). Student presence relates to an individual's ability to identify with the course of study, communicate purposefully and develop interpersonal relationships. Cognitive presence refers to the student's collaborative knowledge construction through exploration, integration and application (Arbaugh et al., 2008; Garrison, Anderson, & Archer, 2010). Relating these key elements to blended learning which focuses on social elements, the Community of Inquiry (CoI) instrument is included in the study to understand students' perceptions of teaching context.

Process factors refer to how learners approach their learning. Generally, ways of learning have been categorized into two orientations. The first approach is deep learning whereby learners attempt to enhance their understanding through relating and differentiating concepts and ideas. On the other hand, learners may just replicate ideas without much analysis or in-depth understanding of concepts (Thomas & Bain, 1984), and such a learning approach is called a surface approach. Process factors are also the result of the interaction between student and teaching contexts. Specifically, the type of approaches to learning that students adopt is dependent on presage factors. Process in student learning can be viewed as an ongoing approach that requires individuals to respond to items related to a specific academic task (Biggs, Kember, & Leung, 2001). For the process factors, student's motive, strategy and approach to learning scores may be compared to other students' scores in the same cohort, so as to examine the variability between individuals in a given academic context. These ongoing approach scores may provide informative evidence about how students handled specific academic tasks. Of course, in an ideal system, we would expect students to be fully engaged in academic tasks optimally, which relates to a deep approach to learning. However, in reality, it may not be so. Previous research highlighted that most undergraduates increasingly adopted the surface approach to learning due to their shifted expectations of the course and a loss of interest in the course (e.g. Gow & Kember, 1990; Sinapuelas & Stacy, 2015). To assess students' approaches to learning, the Approaches and Study Skills Inventory for Students (ASSIST) was used. This instrument evaluates three styles of learning: deep approach, strategic approach and surface apathetic approach. Examples of a deep approach to learning are seeking meanings and relation of ideas; a strategic approach refers to time management and organization; and lastly, examples of surface apathetic approach include lack of purpose in learning and unrelated memorization.

Product factors refer to affective outcomes and institutional evaluation in terms of how much (quantitatively) and how well (qualitatively) the students have learned in the form of grades or qualitative evaluation. Affective outcomes relate to students' feelings about their learning experience. In addition, feedback could be included as it has important effects on student expectations and motivation (Biggs, 1993). Student's product in learning can be quantified by a final grade based on a combination of different tasks or grade point average (GPA). On the other hand, student assessment may be graded qualitatively by a dissertation model in terms of pass/fail or a weighted profile that is defined as "a profile determined by the structure of curriculum objectives" (Biggs, 2011, p. 25). The weighted profile requires students to perform different tasks at varying levels ranging from high understanding to knowledge of terms. For the outcome measure in this study, students' gain in skills (e.g. communication, collaborative skills) and academic performance (i.e. course grade) were assessed.

In summary, the 3Ps model (Biggs, 1989) includes presage factors such as student characteristics (e.g. active learner preference) and teaching context (e.g. instructor presence); process factors such as students' approach to learning; and product factors including learning outcomes. Following Bigg's model, the presage variables that consist of contextual circumstances and personal characteristics could influence learners to adopt a specific learning approach. It could subsequently affect learning outcomes. The 3Ps model also assumes that the presage variable (e.g. the perception of learning environments) can primarily impact the outcomes of learning.

11.3 Purpose of This Study

Based on the abovementioned 3Ps model, an instrument (i.e. 3PsQ) was developed. The key research questions guiding this study are as follows:

1. What are students' perceptions of blended learning environments?
2. What are the relationships among the presage, process and product variables, as defined in Biggs' 3Ps model?
3. What are the influential aspects of students' perceived blended learning environments on the approaches to learning and outcomes?

This study sought to investigate university students' perceptions of blended learning environments and understand their approaches to learning which in turn could affect their learning outcomes. Specifically, the study sought to identify the influential aspects of perceived learning environments and ascertain the extent to which these affect students' approaches to learning. Lastly, this study attempted to highlight particular aspects of blended learning environments that appear to be most amenable to change with the end goal of enhancing learning outcomes.

11.4 Conceptual Framework

Figure 11.1 shows the proposed conceptual model for investigating the relationships among the presage-process-product (3Ps) variables.

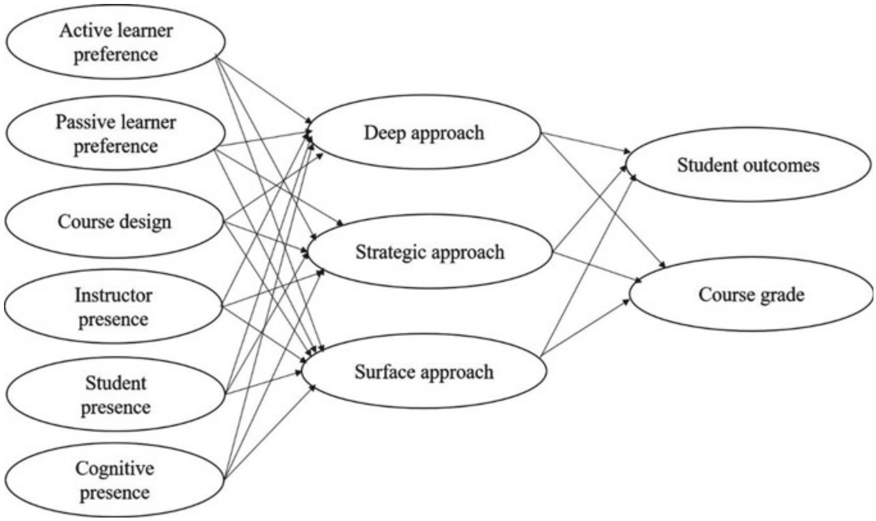

Fig. 11.1 The proposed model for the presage-process-product variables

11.5 Method

11.5.1 Participants

This study was conducted with 109 undergraduates (Age $M = 22.6$; $SD = 2.67$) who took 13-week blended learning courses in the Nanyang Technological University (NTU). The undergraduates came from four blended learning courses conducted by the university.

Ethic clearance was obtained from the university review board. Participants were briefed on the purpose of the study, and the confidentiality of their responses was assured. Data were extracted from the online questionnaire (in English), which took about 20 min to complete. The questionnaire was administered to students at the end of the semester and after the release of course grades.

11.5.2 The Instrument

The 3PsQ instrument contained 54 items, with 5 key constructs. These constructs included learner preferences (i.e. active versus passive); teaching context (i.e. instructor, student and cognitive presence); course design; student approaches to learning (i.e. deep, strategic and surface apathetic); and student outcomes (i.e. skills gained).

For each item, the participants were asked to respond to a self-referring statement on a Likert scale ranging from "1 = Strongly disagree" to "6 = Strongly agree". All items were related to generic aspects of learning in the university blended learning courses. The items of presage were based on the scales used in ASSIST (active and passive learner preferences) and Community of Inquiry (CoI; Garrison et al., 2010; course design and presence dimensions); the items measuring students' approaches to learning were based on ASSIST; while the items measuring student outcomes were based on shortened experiences of teaching and learning questionnaire (SETLQ; ETL-Project, 2005) and course grade.

Exploratory factor analysis (EFA) using principal component analysis as the extraction method and Oblimin (with Kaiser normalization) as the rotation method was conducted to examine the stability of the measurement model. EFA is used because this is the first study that established the 3PsQ instrument, based on multiple measures. In this case, EFA is used to determine the number of factors (Tabachnick, Fidell, & Ullman, 2007) as EFA commonly uses correlations (Flora & Flake, 2017) and this study is examining the relationships among factors in the blended learning environment. Only the items with strong factor loadings higher than 0.3 were used for analysis. A total of 28 items related to the presage was generated. Based on the EFA loadings, the presage comprised six factors: active learner preference; passive learner preference; instructor presence; student presence; cognitive presence; and course design (see Table 11.1). A pool of 18 items related to the approaches in which students learn in the blended learning courses was generated. This process component has three factors, namely, deep approach, strategic approach and surface apathetic approach to learning (see Table 11.2). Finally, the product included the eight-item measure for students' skills gained and course grade (see Table 11.3).

In summary, the 3PsQ consisted of six-factor presage and three-factor process components. Student characteristics have two subscales, namely, active learner preference and passive learner preference. The presence scale has three subscales: instructor, student and cognitive. The approaches to learning scale include three subscales: deep, strategic and surface apathetic. Finally, the product includes student outcomes and course grades.

11.5.3 Data Analysis

The quantitative analysis of the data from the questionnaire was performed using the Statistical Package for Social Science (SPSS) 24.0 and AMOS 24.0. Descriptive statistics (i.e. means and standard deviations) were examined for all variables of the 3PsQ. To examine the relationships among students' perceptions about blended learning environments, approach to learning and outcomes, and Pearson correlation coefficients were analysed. To further understand the presage-process-product relationships, structural equation modelling pertinent to student preferences, course design, instructor, student and cognitive presence and learning outcomes were investigated.

Table 11.1 Factor analysis of loadings for the six presage factors

	Loading
Factor 1: Active learner preference (α = 0.70)	
I prefer instructors who encourage us to think for ourselves and show us how they themselves think	0.770
I prefer exams which allow me to show that I've thought about the course material for myself	0.731
I prefer courses where we're encouraged to read around the subject a lot for ourselves	0.673
Factor 2: Passive learner preference (α = 0.70)	
I prefer instructors who tell us exactly what to put down in our notes	0.711
I prefer exams or tests which need only the material provided in our lecture notes	0.792
I prefer courses in which it's made very clear just which books we have to read	0.739
Factor 3: Course design (α = 0.81)	
What I was taught seemed to match what I was supposed to learn	0.566
I could see how the assignments fitted in with what I was supposed to learn	0.586
The instructor clearly communicated important goals for the course	0.419
Factor 4: Instructor presence (α = 0.90)	
The instructor was helpful in identifying areas of agreement and disagreement on topics in the course that helped me to learn	0.870
The instructor helped keep the students on task in a way that helped me to learn	0.438
The instructor was helpful in guiding the students towards understanding course topics in a way that helped me clarify my thinking	0.865
The instructor clearly communicated important course topics	0.618
The instructor helped to focus the discussion on relevant issues in a way that helped me to learn	0.815
The instructor was patient in explaining things which seemed difficult to grasp	0.586
The instructor helped me to see how I am supposed to think and reach conclusions in the subject	0.715
Factor 5: Student presence (α = 0.87)	
Getting to know other students gave me a sense of belonging in the course	0.660
I felt comfortable participating in discussions	0.868
I felt comfortable interacting with other students	0.849
I felt comfortable maintaining a sense of trust when disagreeing with other students	0.846
I felt the discussions with other students helped me develop a sense of collaboration	0.579
Factor 6: Cognitive presence (α = 0.87)	
Problems posed in the learning activities increased my interest in course issues	0.718
The learning activities aroused my curiosity	0.745
The learning activities motivated me to explore content-related questions	0.872
Brainstorming helped me resolve content-related questions	0.782

(continued)

Table 11.1 (continued)

	Loading
Combining new information helped me answer questions raised in the learning activities	0.805
I can describe ways to test and apply the knowledge created in this course	0.534
I can apply the knowledge created in this course to my work or other non-course related activities	0.837

Table 11.2 Factor analysis of loadings for the three-factor process

	Loading
Factor 1: Deep approach to learning (α = 0.81)	
When I'm reading an article or a book, I try to find out for myself exactly what the author means	0.680
Before tackling a problem or assignment, I first try to work out what lies behind it	0.649
When I'm working on a new topic, I try to see in my mind how all the ideas fit together	0.459
Ideas in course books or articles often set me off on long chains of thoughts on my own	0.818
Often I find myself questioning things I hear in lectures or read in books	0.696
When I read, I examine the details carefully to see how well they fit in with what's being said	0.749
Factor 2: Strategic approach to learning (α = 0.85)	
I think I'm quite systematic and organized when it comes to revising for exams	0.847
I organize my study time carefully to make the best use of it	0.786
I'm pretty good at getting down to work whenever I need to	0.704
I work steadily through the term or semester, rather than leave it all until the last minute	0.670
I put a lot of effort into studying because I'm determined to do well	0.760
I don't find it at all difficult to motivate myself	0.559
Factor 3: Surface apathetic approach to learning (α = 0.80)	
There's not much of the work here that I find interesting or relevant	0.753
Much of what I'm studying makes little sense: it's like unrelated bits and pieces	0.784
I'm not really sure what's important in lectures, so I try to get down all I can	0.652
I've often had trouble in making sense of things I have to remember	0.599
Often I feel I'm drowning in the sheer amount of material we're having to cope with	0.681
I often worry about whether I'll ever be able to cope with the work properly	0.716

Table 11.3 Items for measuring student outcomes in terms of skills gained

Factor 1: Skills gained ($\alpha = 0.88$)
How much of the following skills do you feel you have gained from studying this course?
Knowledge and understanding about the topics covered
Ability to think about ideas or to solve problems
Skills or technical procedures specific to the subject
Ability to work with other students
Organizing and being responsible for my own learning
Ability to communicate knowledge and ideas effectively
Ability to track down information in this subject area
Information technology/computing skills (e.g. WWW, email, word processing)
Factor 2: Course grade
What was your final grade for this course?

11.6 Results

11.6.1 Descriptive Statistics

Students' perceptions towards blended learning were analysed, and results showed that they had generally positive attitudes towards aspects of blended learning. The mean scores for all subscales (learner preference, course design, presence, approaches to learning and outcomes) range between 3.64 and 4.86. Table 11.4 shows the mean scores of the 3Ps variables for the blended learning courses.

11.6.2 Correlations

The relationships among the presage, process and product variables were tested by Pearson correlations. It was found that active learning was significantly related to all variables of the 3PsQ, except surface apathetic approach to learning and course grade. Passive learning was negatively correlated to deep approach ($r = -0.27$, $p < 0.01$) and skills ($r = -0.22$, $p < 0.05$), but positively related to grade ($r = 0.21$, $p < 0.05$). The course design was positively correlated to all presence components and skills. Instructor presence was significantly correlated to all variables of the study, except passive learning. Both student presence and cognitive presence were significantly related to active learner preference, instructor presence, deep and strategic approaches to learning, and skills gained. Student outcomes in terms of skills gained were significantly related to all variables except surface apathetic approach to learning. Course grade was significantly correlated to passive learner preference ($r = 0.21$,

Table 11.4 Mean scores of the 3Ps variables for blended learning

Learner preference		Course	Presence			Approaches to learning			Outcomes	
Active	Passive	Design	Instructor	Student	Cognitive	Deep	Strategic	Surface	Skills	Grade
4.27	4.61	4.79	4.86	4.45	4.54	4.34	4.33	3.91	3.64	3.73
0.86	0.91	0.81	0.72	0.81	0.81	0.71	0.83	0.90	0.64	2.3

Note Last row shows SD values

$p < 0.05$), instructor presence ($r = -0.20, p < 0.05$) and surface apathetic approach to learning ($r = 0.35, p < 0.01$). Table 11.5 shows the correlations of the 3Ps variables.

11.6.3 Structural Equation Modelling

All variables were entered into analysis that was consistent with Fig. 11.1. Active learner, instructor presence and course design did not have any significant relationships with the process and product; hence, they were not included in the final path model. Non-significant pathways were trimmed to produce a parsimonious and descriptive model. The results of model fit supported acceptable fit indices: $\chi^2 = 1840.84$, $df = 1360$, $p < 0.001$, $\chi^2/df = 1.35$, TLI = 0.89, CFI = 0.90, RMSEA = 0.057, 90% CI of RMSEA = 0.050, 0.064. There were significant, positive path coefficients between passive learner preference and surface apathetic approach to learning ($\beta = 0.32$, $p < 0.05$), as well as between surface apathetic approach and course grade ($\beta = 0.43$, $p < 0.001$). Student presence was a positive predictor of strategic approach ($\beta = 0.39$, $p < 0.001$) which had positive effect on student outcomes (i.e. skills gained; $\beta = 0.37$, $p < 0.001$). Likewise, there were significant, positive relationships between cognitive presence and deep approach to learning ($\beta = 0.81$, $p < 0.001$), as well as between deep approach and skills gained ($\beta = 0.53$, $p < 0.001$).

Sixty-six percent of the variance in deep approach to learning was predicted by cognitive presence ($R^2 = 0.66$); 15% of the variance in strategic approach was predicted by student presence ($R^2 = 0.15$); and 10% of the variance in surface apathetic approach was predicted by passive learner preference ($R^2 = 0.10$). Fifty-eight percent of the variance in student outcomes was accounted for by the indirect effect of both student and cognitive presences ($R^2 = 0.58$), whereas 18% of the variance in course grade was accounted for by the indirect effect of passive learner preference ($R^2 = 0.18$). However, the direct influences of student presence and cognitive presence on student outcomes were not significant. Similarly, the direct effect of passive learner preference on course grade was not significant. Figure 11.2 presents the final depiction of the significant pathways of the relationships between presage, process and product variables.

11.7 Discussion

The main goal of this study was to examine students' perceptions of blended learning environments using the 3PsQ instrument. It is likely to be among the pioneer local studies that explored the relationships among student characteristics, teaching contexts and student learning outcomes in blended learning environments. The 3PsQ studied the structure of each learning stage (presage, process and product) and their

Table 11.5 Correlations of the 3Ps variables

	Active	Passive	CD	Inst P	Stu P	Cog P	DA	StA	SA	Skills
Passive	−0.215*									
CD	0.312**	−0.143								
Inst P	0.411**	−0.022	0.715**							
Stu P	0.337**	0.048	0.287**	0.350**						
Cog P	0.362**	−0.162	0.617**	0.682**	0.432**					
DA	0.386**	−0.267**	0.530**	0.476**	0.344**	0.613**				
StA	0.302**	−0.155	0.183	0.257**	0.370**	0.208*	0.388**			
SA	0.123	0.195	−0.164	−0.273**	−0.122	−0.143	−0.048	−0.215*		
Skills	0.250**	−0.223*	0.459**	0.404**	0.458**	0.569**	0.457**	0.459**	−0.190	
Grade	−0.116	0.213*	−0.150	−0.204*	0.031	−0.079	−0.085	−0.154	352**	−0.102

Note CD Course Design; *Inst P* Instructor Presence; *Stu P* Student Presence; *Cog P* Cognitive Presence; *DA* Deep Approach; *StA* Strategic Approach; *SA* Surface apathetic Approach
*$p < 0.05$; **$p < 0.01$

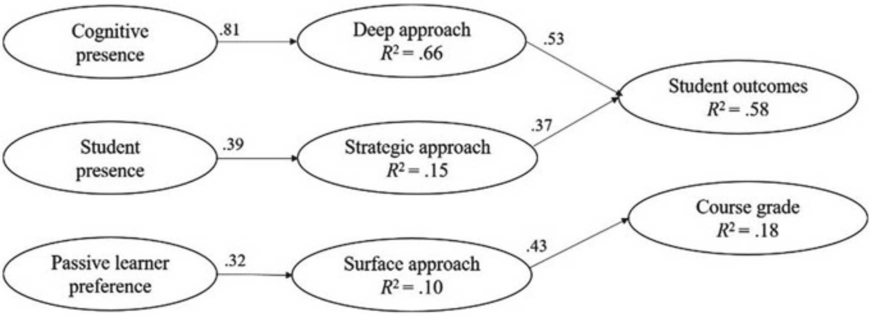

Fig. 11.2 Final structural equation model of the presage-process-product variables

inter-relationships, which could provide insights into university students' approaches to learning in blended learning environments.

Correlational data showed significant relationships among most 3Ps variables. For instance, the negative correlation between active learner preference and passive learner preference was consistent with previous findings (Magana, Vieira, & Boutin, 2018). Active learners are also associated with all presence elements (i.e. instructor, student and cognitive), as well as deep and strategic approaches to learning. However, no significant correlation between passive learner preference and instructor presence was found. This finding suggests that active learners may be more appreciative of instructors' guidance compared with passive learners.

The structural equation analyses revealed interesting yet consistent findings with existing research (e.g. Ho & Kuo, 2010; Saba, 2012). Ho and Kuo (2010) found that students' learning outcomes were amplified through the mediation of several factors, including attentive learning on activities, curiosity and interest in the e-learning environment. Saba (2012) also found significant relationships between students' self-regulated learning (i.e. cognitive strategies) and their learning outcomes in an online learning environment. The blended learning courses in this study included the online components which could engage the students in course participation (e.g. collaborative learning) and self-regulated strategies (e.g. brainstorming). In the survey instrument, student presence includes collaborative learning and course participation, whereas cognitive presence involves brainstorming, curiosity and knowledge application. Student presence and cognitive presence thereby significantly predicted student outcomes (skills gained) through the mediation of deep and strategic approaches to learning.

Interestingly, the surface apathetic approach was related only to course grade, but not the skills gained. This structural equation finding is consistent with the correlational result of the relationships between surface apathetic approach and grade ($r = 0.35$, $p < 0.01$). However, such finding contradicts the existing research that found a surface approach related to lower grades while deep approach related to higher grades (Diseth, 2013). The findings in this study did not support the influence of both deep and strategic approaches on the course grade. The lack of relationship between the deep-strategic approach and grade could be due to the nature of course assessment (Bendixen & Hartley, 2003), for example, if the assessment is focused on factual information, it could require less cognitive resources (e.g. recalling of factual information). Students' self-awareness of their own understanding (through deep and strategic approaches) may also affect the results. Nevertheless, future research should investigate this relationship between the deep-strategic approach to learning and academic performance.

Another noteworthy finding is that although instructor presence was related to all 3Ps variables except passive learner preference, the structural equation result revealed no significant effect of instructor presence on the learning outcomes (i.e. skills and grade). Compared to Türel's (2016) study, the relationship between students' perception of instructor presence was weak. In this study, the items measuring instructor presence primarily focused on communication and social aspect. It is likely that the blended learning courses had less student-instructor interaction, resulting in a lack of instructor presence.

Overall, the findings from this study shed some light on the relationships between the presage-process-product variables. However, there is still room for improvement in establishing a more parsimonious framework that applies to the learning of various forms of knowledge, whether it is factual, conceptual or application. The deep and strategic approaches to learning seemed to be too closely related which suggests that these two factors may not be well differentiated by the participants. As the present study focused on self-report measures, more information should be provided by the blended learning environment (e.g. in the form of behavioural analytics) to understand the dynamic learning process of students.

11.8 Implications

The findings from this study could provide several implications for instructional practices. First, the significant effect of student presence and cognitive presence on skills gained (mediated through deep and strategic approaches) may imply that blended learning could improve learning outcomes in terms of skills gained (e.g. communication, collaborative skills). Both presence elements also predicted the skills gained, indicating that the roles of student presence and cognitive presence are also important in facilitating the use of deep and strategic approaches during the course of study. It is recommended that the course contents should be analysed to ensure the relevance of the appropriate approach to learning which in turn will influence the outcomes. Second, findings of this perception study will be useful to university instructors and practitioners, particularly how the perceived learning environments and the presence elements (e.g. cognitive presence) could affect approaches to learning. Third, this study informs students of the importance of appropriate strategies towards learning at a tertiary level. Besides university instructors and content experts, a strong team of learning experts and multimedia specialists is needed to develop effective blended learning courses. Organizational theorists such as Beckhard and Harris (1987) as well as Cummings and Huse (1989) have argued that initial efforts of adapting new approaches should be seen as practical to increase the likelihood of success. This is particularly pertinent for universities that are adopting e-learning technologies. Lastly, the university needs to assess its initiatives that are targeted to support learning and student outcomes, such as the provision of a framework or criteria to assess the suitability of an e-learning tool for their learners' needs.

11.9 Limitations and Future Research

Future studies could be conceptualized to overcome limitations in this study. First, the sample size for the present study was small. A larger sample size is needed to generalize students' perceptions of blended learning environments and their presage-process-product relationships. Second, only self-report measures were used to assess students' perceptions of blended learning environments. Future studies could include qualitative measures to evaluate students' characteristics, approaches to learning and outcomes. Third, due to the confidentiality and sensitivity of student data, this study relied on self-reported course grades at the end of the semester. This may result in grade discrepancy if, for various reasons, the students did not report their grades accurately. Finally, blended learning resources could vary from course to course. The insignificant findings could be due to differences in instructional practices among the various courses. Future research could analyse the course outline, contents or even course implementation to have a clear understanding of the structure and design of the blended learning courses.

11.10 Conclusion

This study sets out to study students' perceptions of blended learning environments, as well as the relationships between the presage-process-product variables. It revealed university students' perceptions of blended learning environments at the end of the course. It is also the first study to establish and validate the instrument of 3PsQ in a university setting. More importantly, the results showed that the influences of passive learner preference, student presence and cognitive presence on students' learning outcomes were mediated through the type of approaches used. Finally, findings herein contributed to the existing research by establishing the relationships of the presage-process-product model through the application of 3PsQ in blended learning environments.

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Chapter 12
The Evaluation of Informal Learning Spaces in a University

Jason Wen Yau Lee and Peter Looker

> There's a reason why I stopped going to the library when The Hive (a physical learning hub) was built… Definitely location is quite important because The Hive is not only a great place to study…, it really acts as a hub, which is what the whole advertisement is talking about. It really acts as a hub, so when I have class at HSS (Humanities Building), I can just move to HSS and then when I'm done, I can come back to The Hive to study or do work, and then afterwards if I have class in South Spine, I can move to South Spine. It's like, just the right place to shift and move.
> [Student S2].

Abstract This study, situated in a university that underwent a transformation of learning spaces, examines students' use of informal learning spaces with different levels of intentional design to determine what factors influence the way the students use them. Using factor analysis, a 10-item survey on how spaces are perceived and experienced by students loaded into three factors: comfort (5 items), convenience (3 items) and community (2 items). Comfort refers to (a) the way furniture is configured, (b) quality of air circulation, (c) lighting, (d) cleanliness and (e) facilities. Convenience refers to (a) proximity of the learning space to classes, (b) ability to consume food and drinks and (c) ability to use the space for discussions or group work. Community is defined as spaces that (a) provide "privacy" and (b) spaces where the student usually frequents for a particular activity. The findings suggest that intentional design that takes account of all these factors and that takes into consideration how students might move from formal to informal will gain students' preferences, but during the time when classes are held. This study showed that not all factors we detected as those that students see as influencing their choice of informal learning space need to be present under all circumstances.

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Keywords Informal learning spaces · Space design · Comfort · Convenience · Community

12.1 Introduction

Driven by a number of factors including changes to desired pedagogical approaches, increasing use of technology, concerns over retention, student satisfaction measures, global rankings and the need to connect to the so-called "real world", university learning spaces have become both the subject of research and physical redesign (Boys, 2011; Carnell, 2017; Painter et al., 2013). Over the last 30 years, there has been a growing recognition of how space design influences the learning, though learning spaces remain under-theorised (Boys, 2011). The push for research-based pedagogical change has given rise to an awareness of how traditional university classrooms lend themselves to "knowledge-transfer" models of didactic teaching, where teachers become the focus of attention (Carnell, 2017; Universities and Colleges Information Systems Association [UCISA], 2016).

It is important, as Boys (2011) suggests, that contemporary learning theories inform the design of learning spaces. Lave and Wenger's (1991) notion of situated learning, and Meyer and Land (2003) ideas about "threshold concepts" both point towards the idea of learning as "collective practice towards shared social meanings" (Boys, 2011, p. 29). Clearly, this is not only about the space in which learning happens. In order to design future spaces, we also need to continuously evaluate how students inhabit and use spaces, and understand how social meaning is constructed within particular spaces and the relationship among spaces.

Riddle and Souter (2012), in a paper about the student-led design of informal learning spaces, concluded that a significant shortcoming in learning space design is that it frequently takes no account of student perspectives, leading to familiar, but inappropriate designs that are not tuned to student needs. Learning theories alone cannot determine the design but must draw on knowledge of patterns of usage and the qualities of spaces that are conducive to students. Like Franks and Jewitt (2001), Boys (2011) suggests that meaning-making in particular spaces occurs "by the activation of space by our bodies" (p. 29). The significance of the space itself is in how it either enables or inhibits bodily activation.

In this study, we examined a range of informal learning spaces that are differently "activated" by the students. This is not just a matter of space design, but also where space is located relative to other places on the campus, what point of the semester it is, and what time of day it is. Chism (2006, 2.2) observes that "a room with rows of table arm chairs facing an instructor's desk in front of chalk boards conveys the pedagogical approach "I talk or demonstrate; you listen or observe". In this way, space seems to contain, or constrain the behaviour, but it is possible to find other ways of behaving. It is clear, for example, that someone like Harvard professor Eric Mazur (YouTube Video on Interactive Lecturing: https://www.youtube.com/watch?v=wont2v_LZ1E) makes use of standard lecture theatres as described by Chism in a very different way, with students working in groups. Informal learning spaces, more than formal learning spaces, are activated by students. In some cases, they are "found" spaces, while at the other end of the spectrum, they are purposefully designed.

In a discussion of the importance of learning in social settings, Carnell (2017, p. 3) notes that students he interviewed at University College London suggest that it is "in the 'in-between spaces', between classes and lectures, where students felt learning really happens". Yet in the past, one of the corollaries of a built environment consisting mostly of front-facing, teacher-focused, tutorial rooms and lecture theatres was an absence of meaningful, comfortable and purposively designed informal learning spaces, with the implication that students only learn in the classroom (Chism, 2006; UCISA, 2016). Montgomery (2008, p. 123) suggests that learning spaces influence the "social construction of education" where "the *movements* within the space" (and from one space to another) are "socially constructed sources of meanings". This does not mean spaces have a single or finite set of meanings, but seeing meaning in the movement both within and across spaces forms an important background to this study insofar as it points to how informal relate to formal learning spaces and the meaning for students of moving from one space to another.

Discussing a purpose-built informal learning space for mathematics students at Sheffield-Hallam University, Waldock, Rowlett, Cornock, Robinson, and Batholomew (2017) suggest that the provision of a good informal learning space can motivate students to stay and work when there are long timetable gaps and that they provide a sense of a base.

Two other theoretical perspectives can inform this study as the notion of situated learning is linked both to *context-dependent* memory and *learning transfer*. In this case, the idea that the qualities or nature of the physical space is encoded with the learning itself, which, in turn, is better retrieved in a similar physical context (Godden & Baddeley, 1975); and the idea that what is learnt in one situation affects what the learner is capable of doing in another situation (Marton, 2006). One way to think about these theories together in relation to this study is to ask about what is transferred by students from the informal to the formal learning space and back again. How should the formal and informal be designed to facilitate the effects of context-dependent memory and therefore, transfer?

These theoretical considerations can be applied to the building called *The Hive*, a student learning hub at NTU with 56 classrooms enveloped by informal learning spaces. The notion of *continuous* flow from the formal classroom to the informal spaces is important in understanding the intentional design aspects of The Hive. One hypothesis applied to this design principle at NTU comes from an attempt to create a backwards and forwards flow between learning that takes place in the classroom and in informal learning spaces, rather than discontinuity or disjunction between the different spaces.

The following study attempts to analyse students' use of informal learning spaces with different levels of intentional design, across the university, to determine what factors influence the way they use them. Of particular interest are the informal learning spaces designed together with formal learning spaces as in *The Hive*. The aim of this study is to map and evaluate students' use of informal learning spaces across NTU as a way of informing future design.

12.2 Purpose of Study

With the availability of the learning spaces spreading across the university, we seek to develop a better understanding of how these spaces are being utilised. The research questions that drive this study are as follows:

(1) What are the types of learning spaces available in the university?
(2) What are the factors that affect the satisfaction of a learning space?
(3) How much time do students spend in the learning space?
(4) How are the learning spaces being utilised?

12.3 Methodology

12.3.1 Context of the Study

In 2007, NTU convened the Blue Ribbon Commission (BRC) (Nanyang Technological University, 2008), a wide-ranging review of all aspects of undergraduate education. The BRC's comprehensive recommendations released in April 2010 implied a general shift to a more student-centred learning environment. Of particular interest to this study are two of the recommendations of the BRC under the rubric "Building Infrastructure to Support Pedagogical Change". These recommendations were first published in April 2010, and implementation began in June 2010.

3.3.3.1 Building classrooms with configurable space and technology-enabled facilities (p.21)

3.3.3.2 Creating more informal learning spaces (p.23)

Recommendation *3.3.3.2* concerning informal learning spaces is directed at the conversion of under utilised space across the University into informal learning spaces, at the same time upgrading existing informal learning spaces. These should be "adaptable to a variety of collaborative activities and individual learning" (p. 23).

Since 2010, Nanyang Technological University (NTU) has significantly transformed its learning and teaching spaces across the campus, both formal and informal. While this study focuses on informal learning spaces, NTU has attempted to develop informal learning spaces in relation to formal learning spaces, rather than as separate, unrelated spaces, so some understanding of the evolution of formal learning spaces is necessary here. A valuable way of thinking about informal and formal learning spaces is to conceptualise them as overlapping or contiguous, both in terms of the physical nature of the space itself and the way it is used by learners.

Fig. 12.1 The Learning Hub South (The Hive)

The first part of the implementation plan for the formal learning spaces involved converting existing tutorial rooms into collaborative, technology-rich classrooms. From 2010 to 2016, all existing front-facing tutorial rooms were converted to collaborative learning spaces. In 2015, the Learning Hub South (The Hive) (Fig. 12.1) opened with 56 collaborative classrooms of varying seating capacity. In February 2017, the North Spine Learning Hub (The Arc) was opened, adding another 56 collaborative classrooms, bringing the total number of collaborative tutorial rooms across the University to more than 230. Mapping the informal learning spaces, as undertaken in this study, is in part a response to this whole-of-university makeover of tutorial rooms.

An important part of the evolution of learning spaces at NTU occurred after the first 40 tutorial rooms had been converted to collaborative learning spaces in 2011. It was clear that as soon as the rooms opened, students began to inhabit them between classes as informal learning spaces. The fact that this happened (and had not happened in the old front-facing rooms) influenced thinking about the design of the South Spine Learning Hub (The Hive) in terms of the relationship between informal and formal learning spaces, and the way they interact with each other.

12.3.2 Data Collection

Data for this study were collected over a period of 9 months at NTU, beginning with a pilot study in April 2016. The pilot phase consisted of a grounded approach with informal observation sweeps across the university to map informal learning spaces, piloting a survey in four identified locations (see Harrop & Turpin, 2013, for a study of informal learning spaces employing a related methodology at Sheffield-Hallam University). The survey captured anonymous student demographics, time of day, and duration of space utilisation, and the type of activities in which the students were engaged. The open-ended questions captured the reasons for students using a particular space and the affordances of the space they found valuable.

In the final version of the survey questionnaire, the open-ended questions were subsequently categorised thematically, with the 10 most common themes categorised as "space satisfaction" statements. For each space that has been surveyed, respondents rated their satisfaction with the space using a 5-point Likert scale (see Lee, 2017 for more details on the survey questionnaire).

The study was divided into two phases to determine whether the dynamics of usage changed across time, especially as examination week approached. The first phase of data collection was in week 3 of a 12-week semester, while the second phase of data collection occurred in week 10. A total of 1,619 responses were collected in the first phase, and 1,223 responses in the second phase. In addition, focus group discussions with students in the different locations were held to elicit more probing explanations.

12.3.3 Data Analysis

The space satisfaction data collected was analysed using IBM SPSS Statistics v23. An exploratory factor analysis (EFA) was performed on 2,842 valid responses using principle components analysis with a Varimax and Kaiser normalisation, yielding three factors (comfort, convenience and community). The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.74, above the commonly recommended value of 0.6, and Barlett's test of sphericity was significant (χ^2 (45) = 6855, $p < 0.05$). Five items with a range of 0.580–0.801 loaded onto Factor 1 (comfort), three items with a range of 0.538–0.890 loaded onto Factor 2 (convenience) and two items with a range of 0.752–0.830 loaded onto Factor 3 (community). There were no items in the data that were cross-loaded.

12.4 Results

We designated the spaces discussed in this study as "more" or "less" intentionally designed. More intentionally designed spaces (MIDS) are study rooms, tutorial rooms and those in the Library that are usually air-conditioned, have facilities such as power

Fig. 12.2 South Spine study area

sockets and are often actively supported. Tables and chairs may be specially designed to enable group or individual study. On the other hand, less intentionally designed spaces (LIDS) are usually located within areas of high foot traffic such as outside the lecture halls, along the corridors, or on walkways between buildings (Fig. 12.2). LIDS are generally (though not always) areas where students gather immediately before class or in-between classes when there is a small amount of time. As these spaces are located in open areas, the furniture is more durable and built to withstand the elements (e.g. rain and sunshine). Table 12.1 is a brief description of the area surveyed for this study.

12.4.1 Factors that Affect a Space

Based on the EFA analysis, the 10 items loaded into three factors that affect how spaces are perceived and experienced by students. These are what we call the 3Cs—comfort (5 items), convenience (3 items) and community (2 items).

Table 12.1 Description of the MIDS and LIDS surveyed for this study

Learning spaces	Description of area
More Intentionally Designed Spaces (MIDS)	
Library Commons	Air-conditioned study area designed with long tables comfortably seating 6 and individual tables. Students are free to discuss their work but area is generally quiet
Library Quiet Zone	Similar to the library commons but discussion is not permitted
Athena/Minerva (Study rooms)	Air-conditioned area with table space suited for four people. Space is designed as a study area with students observed to be studying individually and collaboratively
The Hive (Tutorial Rooms)	Tutorial room with circular tables for 5 equipped with power sockets and monitors. Students are free to use the rooms when classes are not in session
Global Lounge	Informal space that was designed for students to meet up with small round tables that sit 2. The area originally had a café which has since relocated and evolved into a study area
Less Intentionally Designed Spaces (LIDS)	
Benches Outside LT (North Spine)	Picnic benches that serve as a study bench along the walkways outside the lecture theatres. The area is equipped with fans and power sockets located in the North Spine of the campus
Benches Outside LT (South Spine)	Similar to the above but located in the South Spine of campus
South Spine study area	Open-air area with study tables that sits between 2 and 4 people located along the walkway adjacent to a covered carpark
The Hive (Outside Area)	Circular tables located outside the tutorial rooms that comfortably sits 3–4 people. Power sockets are not always located close
Student Activity Centre	Large air-conditioned informal space run which houses the Student Union that serves as a "hang out" area which has tables for discussion, pool table and console games. The area is designed to be a mixed-use space for both informal gathering and a study area

12.4.1.1 Comfort

Comfort plays a very important role in how learning spaces are seen by students. Here, the term comfort refers to (a) the way furniture is configured, (b) quality of air circulation, (c) lighting, (d) cleanliness and (e) facilities (such as Internet connection, power sockets). Student Q2 shared that "comfort means maybe have a big table like maybe have enough space for me to put my stuff, and maybe the chair or the lighting or the temperature, air-conditioning…".

Furniture configuration refers to the arrangement of tables and chairs. The way the furniture is designed influences the way the space is being used and learners expressed the desire for larger and more comfortable furniture (Harrop & Turpin, 2013). Similarly, our focus group discussion found that students wanted more comfortable seats (i.e. cushioned seats) as they may spend more than four hours at a particular spot during the examination period. The preference for larger furniture is dependent on the purpose of the space that is being used. What this means is that students who are studying individually prefer individual tables so that they do not need to share the space with too many people while circular tables are preferred for group-based discussion.

Air circulation mainly refers to the temperature of the learning space. The study site is located in a hot and humid country with an average temperature of 28 °C but is surrounded by a large green space. Air-conditioning is a norm in the MIDS, but not all students preferred the air-conditioning as the temperature may be too cold especially when spending an extended period of time in the learning space. Some students responded that they preferred the natural outdoor breeze despite the warm and humid conditions, while others responded that they “needed” to have air-conditioning when studying or having group meetings.

Lighting refers to how much light is in a space and plays an important role especially when the spaces are used for studying. Previous studies have found that lighting and natural light were important factors for students (Harrop & Turpin, 2013). In this study, most of the LIDS were located in areas that have natural lighting and normally do not require much additional lighting. MIDS, however, are usually located within buildings that require additional lighting throughout the day to illuminate the space and are therefore well-lit.

Cleanliness is part of the routine building management and upkeep of a space. In general, most of the spaces surveyed had high satisfaction in terms of cleanliness, but LIDS have slightly lower levels of satisfaction. This can be attributed to the fact that these areas are not fully sheltered and are exposed to the elements which may affect the overall perception of their cleanliness. MIDS are inside and normally air-conditioned, giving a perception of cleanliness.

Facilities in this study refer to amenities such as water fountain, vending machines, power sockets and Wi-Fi connections. We observed many students using the space with their laptops, in addition to the study materials (e.g. books, class notes). Given that most students spend an average of three hours in these learning spaces, the availability of amenities such as food, drinks and power sockets was important. However, what was more important to students, as discussed in the FGD, was that given a choice, they would deliberately choose spaces that have power sockets conveniently located. Otherwise, they would have to share the available power sockets to charge their devices. Wi-Fi connection was also deemed important to students because the network connection enabled them to do things like review recorded lectures online.

In summary, the comfort of a space is not dependent on one factor but an overall combination of multiple factors. This was described by Student S3 who explained how she would go about when selecting a learning space:

> First, I will look at the temperature, if it's indoor or outdoor, if it's too hot I wouldn't….outdoors will be out, and if the place is clean, like let's say, the previous person might have [a cup of cold] drink which would make the table wet […] Therefore, I would not choose that kind of place also. So the condition of the whole environment [plays a role]
>
> [Student S3]

12.4.1.2 Convenience

Convenience in our study refers to (a) proximity of the learning space to classes, (b) ability to consume food and drinks—some spaces have restrictions on drinks and food—and (c) ability to use the space for discussions or group work. We found that the convenience of a space is highly related to whether the learning space is located along the walkways outside the lecture theatres or areas that are on the way to the bus stop.

The *proximity* of a space to classes or along main walkways on campus was one of the factors that influences students' preference for a space. LIDS generally scored higher in the convenience factor. For example, spaces outside the lecture theatres and along walkaways were rated high on proximity because they can be used by students as a study or discussion space before or after class. This was shared by Student T7 who describes the reasons he uses the study area along the walkways.

> … normally I will prefer air-condition too so I think the only reason why we like do it (*study*) outside the benches is because it's convenient. So sometimes we have like same lecture together and we have to discuss something after that, it is like a convenient spot. Yeah, because it (benches outside the Lecture Theatre) is the nearest location
>
> [Student T7]

However, we found that students were willing to move around to different learning spaces around campus to their preferred learning space. For example, the learning spaces in the Library (which, though centrally located is not quick to get into) were rated low on "proximity" but is highly popular among the students due to other factors such as the intention of the student using the space.

There is a debate especially within the librarian community (see, for example, Bedwell & Banks, 2013) whether or not to allow food to be consumed in learning spaces. Most students in this study spend between one to four hours in each space. The ability to consume food and drinks enables students to stay for longer and remain focused without having to move (O'Connor, 2005; Waldock et al., 2017). In this study, LIDS usually have no restrictions regarding the consumption of food but MIDS, such as the Library, may have restrictions in the type of food that may be consumed.

Depending on the purpose of using a learning space, the ability to have discussions was also important to students. LIDS are located in open areas which allow for discussion without interrupting others, while MIDS are located within an enclosed area which can sometimes be a "quiet zone" (or may have no restrictions on the conversation). Our study found that students who are looking to study individually would prefer the library quiet zones while students having group discussions will choose to go to areas that have larger tables. These can be either MIDS or LIDS. Certain MIDS were designed for collaborative work (for example, The Hive) where there are facilities such as TV monitors built into the walls and connected to each table allowing for discussion using computers to display work.

Student U3 shared that due to the nature of his course that requires discussion, The Hive allowed him to share the work on screen with his classmates while the benches along the walkways were some of the areas he frequented due to the proximity to his school. He shared:

> Generally, all our assignments are individual and then we have labs but they are done in the lab. Ok because I'm in IEM (Information Engineering and Media), so have the media component. For our writing assignment we have a group assignment. The Hive is a good place to group assignment because you can just connect your computers to any of the TVs or we do it at the carpark benches because it is near my school.

12.4.1.3 Community

The third factor that relates to space satisfaction is what we term "community". Community in this study is defined as spaces that (a) provide "privacy" and (b) spaces where the student usually frequents for the particular activity (e.g. studying, group discussion).

In this study, *privacy* encompasses two things, privacy for individual study and privacy for collaborative work. For the individual study, privacy would mean that the space is free from distractions such as heavy foot traffic or away from the noise in MIDS such as in the library quiet zones. On the other hand, privacy for students engaging in collaborative work is spaces that group work or discussion can happen without being overly distracting to others in the space. This was shared by Student U2 who contrasted Carpark Benches (LIDS) and The Hive (MIDS):

> For me [I prefer a space that is] quiet and not too many people walking around. […] One of the reasons I do not go to the carpark benches is because there are always people walking. I will be distracted to look up […] I will usually come to The Hive rather than the carpark benches because once you find a room, you have your own table. [Therefore,] you just focus on what you're doing and, […] sometimes there will be distractions if people walk in then go out but I think compared to the carpark benches, The Hive is really much better.
>
> [Student U2]

The preference for a space is also affected by the person's familiarity with the space. We found that students usually have a preference for a particular space and would frequent the same space to study or have their group meetings. Our FGD found that students very seldom moved around to use different spaces and often stayed within the same area across the semester.

> I don't usually study on my own, I study with a group of friends every semester is the same group of friends I study with. So I like to study in a group preferably at the library. […] Because we have the same common modules that we are taking, so if there're any doubts

right, we can always clarify with each other but the library is quiet enough to, you know, if you really want to talk, if you want to chit chat, it's not really very advisable, so in a sense, although we study in groups but it's mainly like you're doing your own things unless there's a very difficult problem or something then we will discuss. And even so, it's very minimal discussion. So it's like companionship

[Student V3]

12.4.1.4 Space Usage Time

Students also self-reported the amount of time that they typically spend at any particular informal learning space. To find out if there were changes in the use of spaces across time, data were collected at two time periods: before the mid-semester break (September) and prior to the examination week (November). This is to understand if there are any differences in the amount of time the learning spaces are being used when students are undertaking different activities. Table 12.2 is a summary of the amount of time spent in the different spaces across the two data collection periods. We divided the amount of time spent into three categories: short use (<1 h), medium use (1–4 h) and long use (>4 h).

The amount of time students spent in most of the learning spaces increased towards the end of the semester. This was apparent in the number of students spending over four hours in the learning spaces which had a notable increase across the semester on all the learning spaces. This can be attributed to the fact that the final examination was approaching and students needed to spend time revising their work.

When we compared the space usage between MIDS and LIDS, we observed that the duration a student spends in the MIDS is on average longer than LIDS. At the beginning of the semester, students usually spent 2–4 h in the MIDS, while students spend an average of 1–2 h and the LIDS. A similar trend was observed towards the end of the semester where the amount of time spent in the learning space increased to over 4 h in the MIDS while the amount of time spent in the LIDS increased to 2–4 h.

12.4.1.5 Utilisation of Space

Learning spaces are also areas where students gather to meet for both study and relaxation (Harrop & Turpin, 2013). From the qualitative data observation, we found that most students were working in close proximity to friends or peers although they may not be collaborating with each other all the time. O'Connor (2005) describes the idea of individuals working together as "studying along". This means that groups of students who are sitting together on the same table may not be necessarily studying the same materials but rather enjoy having the company of others who are performing the same task and hence reporting that they are individually studying and group studying at the same time (see Fig. 12.3).

Table 12.2 Time spent in the learning space

	Time spent									
	Short use		Medium use				Long use			
	<1 h (%)		1–2 h (%)		2–4 h (%)		4–6 h (%)		>6 h (%)	
	Sep	Nov	Sep	Nov	Sep	Nov	Sep	Nov	Sep	Nov
More Intentionally Designed Spaces (MIDS)										
Library Commons	3	0	19	7	40	42	22	27	16	24
Library Quiet Zone	3	0	7	8	39	33	38	26	14	32
Athena (Study Room)	5	1	9	4	41	22	19	32	25	42
Hive Inside	5	2	34	25	46	55	8	13	7	4
Global Lounge	5	8	24	23	51	24	17	21	3	24
Less Intentionally Designed Spaces (LIDS)										
Benches Outside LT (North Spine)	11	4	40	35	31	41	13	8	5	12
Benches Outside LT (South Spine)	21	12	35	34	30	36	8	8	5	11
South Spine Study Area	6	4	42	24	35	36	10	18	7	18
Hive Outside	5	7	34	24	46	35	8	21	7	13
Student Activity Centre (SAC)	9	7	43	39	35	33	5	11	8	10

< 1 hour	1-2 hours	2-4 hours	4-6 hours	> 6 hours
• 42% taking break • 39% individual study • 25% meeting friends • 16% group study	• 62% individual study • 39% group study • 30% meeting friends • 27% group meeting	• 73% individual study • 50% group study • 26% taking a break • 26% group meeting	• 83% individual study • 47% group study • 19% group meeting • 17% meeting friends	• 84% individual study • 52% group study • 23% group meeting • 21% meeting friends

Fig. 12.3 Purpose of space usage by time

We found that students who spent under an hour in the learning space were using it as a transitional space with 42% self-reported that they were taking a break. Areas where students commonly spent under an hour are mainly located in LIDS such as walkway outside the lecture theatres making it a convenient space for the students to quickly catch up with each other before or after class.

Individual study was the most commonly reported activity for short usage of the space. If the space is being used for long use, the number of individual study increases to 80%. Students who spend more time at a learning space are likely to be both studying individually and studying along with their friends which is consistent with the findings from O'Connor (2005).

12.4.1.6 Implications of the Study

Students are likely to spend a longer time in spaces that are more intentionally designed, as compared with less intentionally designed spaces. Figure 12.4 is a representation of student's ratings of comfort and convenience of the learning spaces. We observe that most MIDS are rated high on comfort and convenience except the library. The low convenience rating of the library is attributed to the fact that the

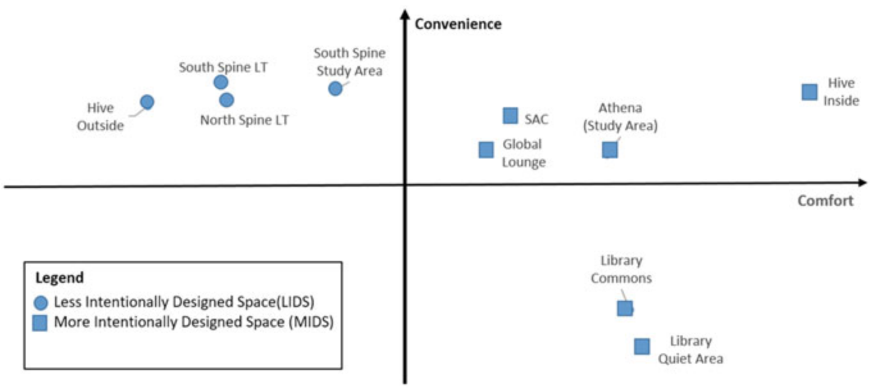

Fig. 12.4 Rating of spaces—comfort versus convenience

study areas are located several floors inside the library building and the policy where food is not allowed to be consumed within the premise.

Spaces rated high on comfort have a higher number of students who spend over 4 h in this space (refer to Table 12.2). The MIDS scored high on comfort because they have been specially designed with facilities such as lighting, air-conditioning, power socket and furniture suitable for studying. The purposively designed space makes the environment suitable for students to spend a longer period of time in the space. Therefore, spaces that are more intentionally designed as informal learning spaces are areas where students will gather for a longer period of time.

Convenience appears only to play a role depending on the amount of time students spend at a particular learning space. The longer the time students spend at a particular location, the less important the convenience is as a factor for their choice. For example, both the library spaces scored low on convenience but they are popular spaces for the students who want to concentrate on studying and they are not transitional spaces. On the other hand, spaces such as benches outside the LT which generally scored lower on comfort but high on convenience are mainly used as transitional spaces before and after class.

While the Hive was a highly rated in comfort and convenience, the number of students who use the space long (>4 h) was much lower compared to other MIDS, such as the study rooms (Athena) or the Global Lounge. The simplest explanation for this is that these learning spaces in The Hive have dual purposes, serving as pre-booked tutorial rooms that students are free to use whenever classes are not in session. Given that there are classes throughout the semester, it is quite unlikely that students will be able to have the tutorial rooms themselves for long periods. This was pointed out by Student U3 who considered it to be lucky to find an empty classroom:

> … for places like The Hive, if you are lucky to get an empty classroom. It is actually quite quiet like even if it's noisy on the outside, it's actually pretty quiet in the classroom and generally people come to The Hive to study so they don't really make a ruckus in the classroom even if you're sharing with other people… yeha. So unless you are doing a presentation which could be like noisy, if not I think it's generally okay.
>
> [Student U3]

12.5 Limitations and Future Direction

Although the sample size of the study is relatively large, the findings of this study were limited to respondents from a Singaporean university. This means that there is a possibility that other factors such as cultural differences or the climate could affect the student's preference when selecting a learning space. Therefore, one future direction for this study is to conduct the survey in other institutions around the world to determine if the same pattern holds on space satisfaction.

This study was conducted during the day (between 10 a.m. and 3 p.m.). Therefore, the learning space usage patterns during the night were not captured. There is a possibility that the usage patterns between day and night may differ. In addition to that, the 10 learning spaces surveyed were “popular” areas that are clustered around the main campus. There are many other learning spaces that are located within the College and residential halls that are frequented by students that can be part of future studies.

There is a lot more to learn about informal learning spaces, and how they are used by students. We intend to further examine other informal learning spaces at NTU, especially now that a new learning space called “The Arc” has been built very close to the main Library. This would help inform the future design of spaces and also help improve the current space design.

12.6 Conclusions

Both specific inferences about the spaces at NTU and general inferences about factors favouring certain informal learning spaces can be drawn from this study. However, it is clear that there is no single combination of factors that applies across all times and circumstances. While out of the three factors—comfort, convenience and community—comfort and convenience are the two most important, even low convenience spaces are preferred (with a high comfort rating) in long duration usage (see Library commons and Library Quiet Area in Fig. 12.2).

In terms of the time in the academic year, it appears that the space that is strongly favoured for both comfort and convenience during the time of semester when classes are held, The Hive, drops right off in usage once classes finish and students are studying for exams. The high score for convenience is only applicable when it can be a “hub” or an anchor space during class time when classes are occurring in and around it. When classes are running, however, The Hive registers a high positive score for all three factors.

Of all the informal learning spaces on campus, those in The Hive were most intentionally designed in terms of the relationship between formal and informal spaces. In other words, it is not just the informal learning spaces themselves that received attention, but the way that the informal and formal learning spaces worked together. Two features of this can be mentioned. First, informal learning spaces flow around the classrooms. No two classrooms are joined together, and the informal spaces are designed around and between them. Secondly, the classrooms have glass internal walls so that the visual effect is one of the classrooms and informal spaces working together. Thirdly, the classrooms themselves are purposely accessible to students as informal spaces when there is no class. All this had the intention of creating a flow from the formal to the informal and back again (This also applies to the new North Spine Learning Hub, The Arc, which is yet to be evaluated.).

There needs to be a variety of informal learning spaces, including the transitional spaces, like those outside lecture theatres as learning can take place anywhere (Chism, 2006). These spaces serve as a transitional point for students to gather in-between classes or serve as a common location for students to work together on their assignments across the semester. While these spaces are not rated highly on comfort, they are conveniently located and popular among students. The use of space is therefore dependent on the intention of the user, and a variety of spaces is needed to cater to these different needs. This can be seen in how Student U4 and her friends choose an informal learning space:

> I was just thinking like I think it depends on what like either you or your friends you're studying with wants from like the environment. In a sense like, I have some friends who don't like it when it's too quiet so then we will go to places maybe like The Hive because you get a room you can at least still talk to your friends. Or like I sometimes study at like SPMS (School) because it's near my [residential] hall, so like the open area there is actually quite good because it is quite quiet, and most importantly is to have the power socket [so that I can] charge [my] laptop - that is like must check. Another thing is air-conditioning, if it's … if I forgot to bring a sweater then I will probably be at the carparks because like it's just nice whereas there are some places that are too hot or too cold yeah so it has to be right
>
> [Student U4]

In terms of tentative more general conclusions, it seems that intentional design that takes account of all these factors and that takes into consideration how students might move from formal to informal will gain students' preferences, but during the time when classes are held. Our study has shown that not all factors we detected as those that students see as influencing their choice of informal learning space need to be present *under all circumstances*.

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Chapter 13
Looking Back, Looking Forward

Seng Chee Tan and Shen-Hsing Annabel Chen

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.

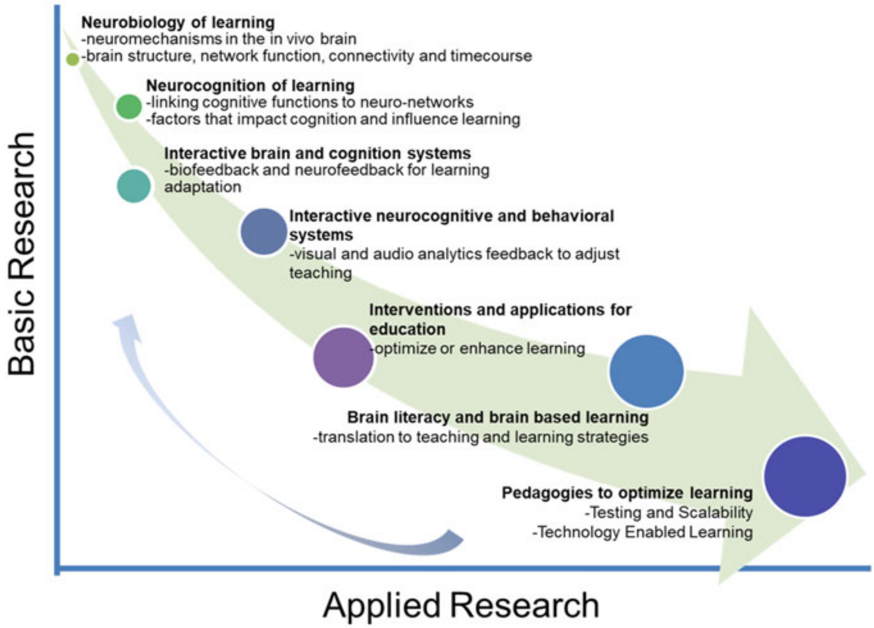

Fig. 13.1 Traversing basic and applied research nexus for neuroscience and learning

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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