NIE
NATIONAL INSTITUTE OF EDUCATION
SINGAPORE

# Learning Sciences

Wong Lung Hsiang, Jan Mingfong and Rose Liang

NIE Working Paper Series No. 1
Series Editors: Lee Wing On and David Hung
Executive Editors: Helen Hong and Michael Tan

An Institute of
NANYANG TECHNOLOGICAL UNIVERSITY

***Series Editors***
Lee Wing On and David Hung

***Executive Editors***
Helen Hong and Michael Tan



**About NIE Working Paper Seres**

The *NIE Working Paper Series* is intended as a means of regular communication between the mutually dependent spheres of theory and practice. The issues surrounding educational provision are often permutations of essential problematics that defy definite solutions. The intended audience for this publication are policymakers, school leaders and practitioners with an interest in how theoretical and empirical perspectives inform practice. Forward and outward looking, these Working Papers are conceptualised with a local issue at hand, and will survey international and local state of thought to assemble a principled response appropriate for our context. As educational problems are often multifaceted and complex, the Working Papers also aim to provide a means for readers to establish clarity by proposing new ways of looking at old problems and providing illumination into the numerous articulating parts of the educational complication. The Working Papers are published in a highly readable style, and appended with an expanded exposition and comprehensive reference for readers who want to know more.

ISBN: 978-981-07-9644-0

# Foreword

Dear colleagues,

I am proud to launch the inaugural issue of the *NIE Working Paper Series*. This Series is meant to strengthen the well-established bridge between the Ministry of Education, Singapore (MOE) and the National Institute of Education, Singapore (NIE) by ensuring that the conversation between policymakers and education researchers continues to thrive. We hope that this lively channel of communication will help Singapore's education system meet the challenges of the rapidly changing world.

Written by both NIE staff and MOE secondees, these working papers will share research ideas about education topics, and will elicit feedback from MOE policymakers. This allows the ideas to be constantly evolving, morphing and changing, and it is through this that we may be able to identify what will work for the system today and beyond.

As the Series progresses and more issues surface, the interaction will extend across different stakeholders as well as different topics and perspectives, thereby creating a more holistic dialogue on issues related to Singapore's education landscape. It is hoped that the discussions generated will help inform practice and will be of benefit to policymakers, school leaders, practitioners and, ultimately, students.

This issue, entitled "Learning Sciences", provides a report of the state-of-the-art literature on the learning sciences. It first takes readers through the history of the learning sciences and explains the reason behind the plurality in "sciences". It then discusses the important topics of how people learn at the cognitive, social and cultural levels; how new methods of research are being developed to better serve teachers and students; how we can transform practices into meaningful ones by appropriately designing learning materials, tasks and environments;

and finally how to translate and scale up research. It concludes by recommending certain methods and that positively affecting practice is the main goal of the learning sciences.

With that, may I invite you to start engaging in talk through the first issue of the *NIE Working Paper Series*. I wish that all parties have fruitful and insight conversations.

Professor Lee Wing On
Dean
Office of Education Research, NIE

# Learning Sciences

*Wong Lung Hsiang, Jan Mingfong and Rose Liang*

## Introduction

It is widely acknowledged that our current education system is inadequate when it comes to tackling 21st century challenges. It is a brave new world that demands critical thinking, creativity, problem-solving and social skills. 21st century competencies, self-directed learning, collaborative learning, knowledge building and game-based learning have emerged as trendy terms policymakers, government officials, researchers, school leaders, teachers and even parents refer to when they highlight the importance of learning in the 21st century. The learning sciences field is an emerging research direction aiming to unpack these learning approaches and other emerging research topics. This research community asks questions about how people learn both as individuals and within communities. It interrogates the validity of traditional research methodologies and develops tools for conducting research. In rethinking learning and asking new questions about learning, its ultimate goal is to reform and transform learning practices within and beyond classrooms by design.

In a nutshell, the learning sciences field aims to answer and align the following inquiry questions:

1. How people learn: The learning sciences seek to answer how people learn at the cognitive, social and cultural levels, through cross-fertilisation of multiple disciplines such as sociology, psychology, domain-specific learning theories, linguistics, neuroscience and computer science.
2. How to conduct research: New research methodology is developed to address the limitations of the mainstream-controlled experiments and quasi-experimental (i.e., experimental versus control groups) methodology.
3. How to transform practices with design: Going beyond designing learning materials or learning tasks, as what typical instructional

designers would do, learning scientists are inspired to design learning environments and learning cultures, with a strong emphasis on addressing the needs of eventual translation and scaling up.

This working paper provides an overview of the history and the salient characteristics of the learning sciences discipline, the state-of-the-art research in the learning sciences locally and internationally (with a special emphasis on how such academic endeavours may inform practice and policies), and the future recommendations for advancing the field and bridging the gap between academics (theory) and practice in the Singapore context.

## Section 1: Learning Sciences Research as Agent of Change—An Introduction

### *21st century education challenges and the learning sciences*

As mentioned above, our current education system is inadequate when it comes to tackling 21st century demands. While mainstream education systems still foreground content mastery, the brave new world demands critical thinking, creativity and problem-solving skills. Policymakers, researchers and educators have sensed the pervasive challenges and are eager to provide solutions, providing quick fix only deters the great opportunity to make a change. Although Singapore students have performed well on international academic assessments, such as PISA (Programme for International Student Assessment), they are not noted for being self-directed learners or having the disposition to be creative and innovative. On the other hand, soft skills—emotional and social intelligences that help them to adapt to the ever changing "flat" world (Friedman, 2005)—are often less foregrounded than cognitive skills in the current education system. Though we have moved on to the 21st century, the mainstream education system resembles the early 20th century education system. It follows a factory model that is viewed as not being scientific (Sawyer, 2006) and has been criticised by John Dewey as teaching compartmentalised subjects with direct instruction approaches. The mainstream view of knowledge and learning—viewing knowledge as indisputable facts and learning as content mastery—still prevails in schools and societies. It is deeply rooted in the public mind through public education.

The 21st century demands raise questions about how we learn, what we learn, where we learn and, more fundamentally, why we learn (Robinson, 2010). Philosophers, scientists, sociologists, educators and those who are motivated to learn have asked these very questions. We have developed research methodologies to systematically understand how learning can be done more effectively and have established research paradigms to understand these questions. Educational psychology, educational technology and instructional design are disciplines developed specifically for education in order to understand how learning takes place in and beyond the classroom context. In fact, these domains have contributed to most of our knowledge about and practices of learning.

The question is, if there are rich research traditions and well-developed research paradigms already in place, why is there a need to develop new research orientations and methodologies, such as the learning sciences? In developing new education research methodologies, there is an assumption that mainstream research methodologies are inadequate in understanding and solving certain learning issues. The learning sciences field was developed to expand the research that other research paradigms have established while going beyond their scope and methodologies. It interrogates the established under several issues: the design of learning environments and sociocultural issues of learning.

Before we delve into the learning sciences, we briefly discuss three mainstream learning perspectives: behaviourism, cognitivism and constructivism. These learning perspectives underpin major education research methodologies, and they are often assumed in everyday learning practices, in how teachers teach, in how students learn, and in the education policies made by key decision-makers.

1. Behaviourism: From a behaviourist perspective, the human mind is seen as a black box which is too opaque to unpack. Research methodologies informed by this paradigm focus on “overt” and “measureable” behaviours. Direct instruction and content mastery assessment emerge as its direct educational applications. Quantifiable learning outcomes are often employed as evidence of

learning, while observable but unquantifiable learning processes are largely bypassed.

2. Cognitivism: Cognitivism seeks not to bypass the black box, but to unpack it in order to understand the internal processes of the mind. In this paradigm, memory, prior knowledge, problem-solving, misconception, structure of knowledge, cognitive load and information processing, to name just a few, emerge as research foci. Researchers often design and conduct experiments in the laboratory or in a well-controlled environment to understand these mental processes. When applied to education, researchers and educators seek to enhance internal mental processes such as improving problem-solving skills, retention of memory, transferring knowledge from one area to another, and so on.
3. Constructivism: The goal of constructivism is not to scrutinise "what is in the head" but "what the head is in" (Cole, 1996). It emphasises the meaning-making processes associated with activities. From a constructivist perspective, knowledge does not reside in the head or in books. Rather, it is situated in social, cultural and historical contexts. Knowing emerges when one actively constructs meanings in activities. Learning, therefore, is a byproduct of one's meaning-making process. Socio-constructivism conceives learning as a social process; therefore, it emphasises the nature of the social process when it accounts for how people learn. Agency, sense-making, collaborative learning, self-directed learning and the culture of learning are learning concepts that emerge from the constructivist perspective.

In a nutshell, the mainstream 20th century education system is built on a behaviourist legacy and partially informed by cognitivism and constructivism. These perspectives underpinning the mainstream school system also resonate with public understanding and imagination about education even in the first decade of the 21st century. In unpacking the 21st century demands in education, we maintain that the challenge lies not in how much we conduct self-directed or collaborative learning, as they are often interpreted vaguely and differently by different stakeholders. Rather, the challenge is how we *redesign* a 21st century education system based on rigorously research methodologies that inform both "what is in the head" and "what the head is in".

## *What can the learning sciences do for 21st century education?*

It is essential to understand where the learning sciences is in the education research methodology landscape. We briefly review three other fields of study that historically predate the learning sciences, namely, educational psychology, educational technology and instructional design. They are three major research methodologies developed specially for education. Educational psychology investigates fundamental issues of learning, such as human development, motivation, intelligence, emotion, cognition and disability. Educational technology and instructional design, on the other hand, are applied sciences that address issues of pedagogy and technology.

### *Educational psychology*

Educational psychology has gone through significant changes and development over the years as its central premises have shifted from behaviourism to cognitivism and finally to constructivism. Informed by psychology and often taking behaviourism and cognitivism perspectives, it often conducts research in controlled environments where quantitative approaches reign supreme. The findings from such a research approach provide insights and explications of learning within well-defined and controlled environments.

However, such findings are often not directly applicable in authentic contexts where the phenomena are too rich and complex to be managed, not to mention controlled. Those who take the constructivism perspective query the need to understand classroom culture, discourse patterns and power relationships. However, these are not questions raised by the mainstream educational psychologists. A subgroup of educational psychologists adopts research methodologies from anthropology, linguistics and sociology; therefore, qualitative research approaches, such as ethnography and participant observation, also have a place in the emerging cultural psychology (Cole, 1996).

In a nutshell, educational psychology has evolved to cover more ground once bypassed by the mainstream educational psychologists, especially when they incorporate research methodologies developed by sociologists, social linguists and ethnographers. This development

is positive but insufficient for 21st century education. Beyond this basic understanding, there is always a need to apply the theories to practices.

### *Educational technology and instructional design*

Educational technology and instructional design are applied sciences that drew inspiration mainly from behaviourism before the 1970s and cognitivism after the 1970s. After the 1990s, there appeared a growing interest in adopting constructivism and socio-constructivism as guiding learning lenses. From a historical perspective, there exists a parallel development among the three major research methodologies. In the 1950s, they all assumed a behaviourist perspective when it came to core learning premises.

While educational psychology aims to understand the input and output of learning, instructional design focuses on making the input and output more effective. Educational technology, meanwhile, aims at designing and using technologies to facilitate content delivery and mastery. However, they also contribute to education in different ways. As applied sciences, educational technology and instructional design differ from educational psychology in their interventionist agenda—designing and experimenting with pedagogies and technologies in various learning settings to improve learning—as defined by behaviourism, cognitivism and constructivism.

### *The learning sciences*

Before the 1990s, controlled experiments, quasi-experiments and quantitative research methods were the mainstream methods because “contexts” (such as social relationship, classroom culture, power hierarchy) and “human agency” were often purposefully bypassed or viewed as too challenging to study scientifically. Constructivism and socio-constructivism, however, are learning perspectives grounded in the relationship between the historical, social, cultural and material contexts, and human agency. With constructivism and socio-constructivism assuming a more central role in how we view learning, the established research methodologies—educational psychology, instructional design and educational technology—necessarily responded by reinventing themselves. Developing new research methodologies to unpack the challenges is also a legitimate approach.

The learning sciences emerged in the 1990s, at a time when constructivism and socio-constructivism began to challenge the mainstream learning perspectives of cognitivism and behaviourism. Coupled with the social turn in understanding learning and research, sociocultural learning theories such as situated learning (Brown, Collins, & Duguid, 1989), community of practices (Lave & Wenger, 1991), socially and culturally distributed cognition (Cole, Engestrom, & Vasquez, 1997; Hutchins, 1995), and new research methodologies, in particular Design-Based Research (DBR, see below; Barab & Squire, 2004; Brown, 1992), were proposed and gradually developed through collaborative effort to a new sciences of learning, a new research paradigm with dedicated researchers around the world.

## *Characteristics of the learning sciences*

The learning sciences represent a radical shift in viewing (1) how people learn, (2) how to conduct research, and (3) how to transform practices with design.

### *How people learn*

Since its early beginnings, the learning sciences has called for different perspectives about learning. Brown, Collins and Duguid (1989) suggest that learning is socially and culturally constructed through personal meaning-making processes. The constructive perspective views learning as an enculturation process. Knowing is always the product of specific contexts, activities and objectives. Therefore, the local culture, authenticity of activities, tools, appropriate guidance to the learners and learners' readiness to learn (Bransford, Brown, & Cocking, 2000) all play critical roles in how people learn. In a nutshell, the learning sciences seek to answer how people learn at the cognitive, social and cultural level. A sociocultural learning paradigm employs a much broader unit of analysis (e.g., mind-in-community), seeking to understand not only how the mind works, but also how the mind functions within its social, cultural and material boundaries and practices.

### *How to conduct research: Design-based research*

As an emerging research methodology, DBR (also known as design research or design experiments) has yet to develop itself into a

comprehensive research methodology like many quantitative research methodologies, or even qualitative approaches (e.g., ethnography and case studies; Sandoval & Bell, 2004). However, learning sciences researchers generally agree on the following characteristics of DBR (Barab & Squire, 2004; Jan, Chee, & Tan, 2010b):

1. the design in DBR is informed and guided by theoretical constructs of learning;
2. DBR engineers the learning context/environment in order to transform current learning practice;
3. DBR studies learning in the designed context, which is also shaped by the local social-cultural-material environment; and
4. DBR seeks to improve design and develop context-laden theories via iterative design and enactment.

### *How to transform practices with design*

The second difference is that the learning sciences seeks to transform practices by design. Specifically, learning scientists design theory-informed tools (e.g., ICT tools), activities (e.g., inquiry, problem-based learning), and practices (e.g., online communities). Due to the pivotal role of design, learning sciences researchers are committed to developing research methodologies that interrogate (1) how we may design learning environments, (2) how the designed environments can be enacted by participants or learners given the differences in local cultures and contexts, and (3) how to iteratively improve the design based on research findings. In fact, the DBR methodology is developed continuously to realise values stance. Collins, Joseph and Bielacyzc (2004) related such a methodology to the term “Design Sciences” (Simon, 1969), as opposed to “Analytic Sciences” in which the latter is typified by experimental-versus-control group (i.e., experimental design) studies. Whereas experimental design studies tend to be clinical, DBR emphasises eventual adoption in school practices (Wong, Boticki, Sun, & Looi, 2011) and therefore must be situated in real-life learning environments where there is no attempt to hold variables constant (Roschelle, Rafanan, Estrella, Nussbaum, & Claro, 2010).

In making the above argument, we do not suggest that the learning sciences is a brand new research paradigm developed from scratch

and can be clearly separated from traditional research paradigms in education. Rather, learning sciences is an interdisciplinary field that incorporates scientific and humanistic methodological orientations to achieve two critical objectives. For example, ethnography, case studies and other qualitative research methodologies are often employed by learning scientists as ways to understand learning and design *processes*. When researchers reach sufficient understanding of their learning designs, pre- and post-tests are also employed to understand the *outcome* of the learning design. Table 1 presents the similarities and differences among the major education research methodologies (approaches or paradigms) discussed above.

### *Institutionalising learning sciences*

Academic programmes and research centres are set up to develop the field and localise as well as contextualise research and knowledge. The United States took the lead in pioneering the field in the 1990s while Asian countries followed up in the first decade of the 21st century. In the United States, University of California-Berkeley, University of Wisconsin-Madison, University of Michigan-Ann Arbor, Northwestern University and Indiana University-Bloomington are among the pioneers in the learning sciences. Recently, Arizona State University pioneered a university-wide research initiative with the establishment of the Learning Sciences Institute (LSI). The International Society of the Learning Sciences (ISLS) was established in 2002, with the aim of bringing together academics, professionals and students seeking to advance the sciences and practices of learning. ISLS is now organising the International Conference of the Learning Sciences (ICLS) and the Computer Supported Collaborative Learning Conference (CSCL) in alternate years, and publishes two prestigious journals, namely, *Journal of the Learning Sciences* (JLS) and the *International Journal of Computer Supported Collaborative Learning* (ijCSCL).

In Asia, the earliest community of studies in learning sciences arose in China during the late 1970s, where pockets of education researchers began to research the natures and essence of learning. Two landmark developments were the publication of *The Dictionary of the Learning Sciences* (学习科学大辞典) in 1998, and the establishment of the National Society of the Learning Sciences (全国学习科学研究会) in

Table 1. Similarities and differences among education research methodologies (approaches).

| Research Paradigm | Objectives | Major learning perspectives | Inspiration for Research Methodology | Design and Intervention |
|---|---|---|---|---|
| Educational Psychology | Understand learning | Behaviourism, Cognitivism Constructivism, Socio-constructivism (emerging) | Mainly informed by by Psychology Sociology, Anthropology and Social Linguistics, etc. (emerging) | Not important |
| Instructional Design | Making learning more effective | | | Yes |
| Educational Technology | Making learning more effective | | | Yes |
| Learning Sciences | To understand learning and inform how we may design cultures, ecologies, pedagogies and technologies for learning | Cognitivism Constructivism and Socio-constructivism | Sociology, Anthropology and Social Linguistics, etc. Design-based Research | Design is informed by learning theories Design is iterative Design as hypotheses Theorising design |

2000. Despite their emergence in almost the same period of time, the international and the Chinese communities of the learning sciences barely interacted with each other. The two communities differ from each other in many aspects, including research objectives, stances, methodologies and the academic backgrounds of their community members. Nevertheless, one unique contribution that the learning sciences community of China can potentially offer to their international counterpart is the association and integration of relevant teaching by renowned Chinese philosophers/educators, ranging from Confucius (孔子) and Zhu Xi (朱熹) to Tao Xingzhi (陶行知) and Cai Yuanpei (蔡元培), with modern studies in the learning sciences.

In other parts of Asia, there are a growing number of scholars and teams who identify themselves as learning scientists. Most of them come from Japan, Hong Kong, Taiwan, Israel and Singapore, with stronger emphasis on computer-supported collaborative learning or knowledge building research. In particular, after a decade of endeavours in relevant studies conducted by various faculties, the Hong Kong University established “sciences of learning” as one of its strategic research themes in 2009. There are two relevant research centres in Southeast Asia, namely, the Learning Sciences Lab (LSL) established by the National Institute of Education, Singapore (NIE; see Section 3) and the Learning Sciences Group established by the University of Malaysia Sarawak (UNIMAS).

## Section 2: International Research Trends of the Learning Sciences

Section 1 has provided a general and historical account of the learning sciences and its interdisciplinary nature in the international context. This section continues with international research trends related to the development of concepts and theories to describe, understand and research on learning and how it happens. We identify the two main international trends: firstly, a conception of learning that situates these trends firmly in the sociocultural domain or more precisely in the interplay between the individual and sociocultural domains; and secondly, in the organisational/systemic aspects of learning.

### *Trend one: Interplay between the individual and sociocultural components*

We discuss the two components of this interplay separately—the individual and sociocultural components—and the specific concepts and themes associated with these two components.

#### *The individual component*

This component is characterised by two themes in understanding individual learning, the importance of the mind and its workings or the mental processes of learning and the importance of practice-informed concepts that identify specific skills and competencies that student will need to prepare themselves for 21st century learning. In this focus on mental processes of learning, the following concepts are relevant.

*Sense-making and meaning-making.* Sense-making is a human activity in which people make sense and interpret what happens to them through their senses. Research suggests that students come up with their own perspectives and make their own interpretations/meanings of what is presented to them in order to learn. These personal interpretations, that is, meaning-making, are pedagogically significant and their consideration is important for effective teaching.

*Representations.* These are ideas or theories that people create in the mind, which represent some aspects of the real (or perceived) world. These may be in form of symbols, words, numbers (statistical representations), models or schemas. Representations are interpretations and are important in meaning-making processes when individuals develop and negotiate such mental representations as part of their learning, discarding, taking up or integrating them.

*Conceptual change.* This refers to shifts in beliefs and concepts that are necessary for learning to happen. Conceptual change in the learning sciences has been discussed in relation to student and teacher learning. The important idea behind conceptual change is that a person has accumulated prior knowledge or “mental structures” that they have developed to make their own sense of events. These may be intuitive, half-formed or misconceptions about the workings of the world that a person brings to the learning situation and impact on their

understanding; for example, of subject-related topics such as Science (Physics and Biology) and Math. Given this teachers, therefore, need to design lessons to recognise and leverage these prior conceptions (which tend to be ignored in traditional teaching approaches) to help students learn. Conceptual change has also been discussed in relation to the professional development of teachers in which it is noted that in the current information-based economy, teachers have to undergo and manage a fundamental shift in educational paradigm towards social constructivist approaches to teaching and learning. Thus, the idea of conceptual change is very important in the learning sciences and an important goal of teaching and learning and subject of many research studies.

The above-stated aspects are interlinked to present an understanding of the learning process at the individual level. The focus is on the individual and the mind in which learning is considered a process of *sense-making and meaning-making* via *representations*. These representations need to be taken into account to support conceptual changes required for learning.

With respect to the focus on practice-informed concepts that identify specific skills and competencies required to prepare learners for 21st century learning, the following concepts are relevant.

*Inquiry-based learning.* Inquiry-based learning or inquiry learning is an approach to learning in which the student is actively engaged in the learning process that tends to be self-initiated. The teacher acts as facilitator enabling students to create knowledge, to become problem solvers and critical thinkers, and learn how to gather, apply, analyse and evaluate information. Specifically, the student forms and asks his/her own questions and hypotheses, test these hypotheses, and, in turn, draw their own conclusions (Schraw, Crippen, & Hartley, 2006). An example of inquiry-based learning is problem-based learning, an intervention strategy in which students learn about a subject through the experience of solving purposely ill-structured problems.

*Higher-order thinking.* In higher-order thinking, Bloom's taxonomy (Krathwohl, 2002) of different types of learning specifies different

thinking skills, such as analysis, evaluation and synthesis may be noted. Inquiry, problem-solving and higher-order thinking skills involve critical thinking, the learning of complex judgmental skills and creative thinking which allows for the creation of new knowledge where novel and useful products are produced (Mumford, 2003).

*Self-regulated learning.* The idea of self-regulated learning also involves a range of pedagogical practices and skills, such as reflection and metacognition (thinking about thinking; Sawyer, 2006) to develop individual habits or dispositions towards self-regulated learning, lifelong learning and independent learning.

These practical-informed concepts related to individual learning are intertwined and considered as competencies needed for a knowledge-based economy.

### *The sociocultural component*

In this interplay between individual and the sociocultural components, it is stressed that social interaction is central rather than peripheral to learning. Social interaction can vary from two people interacting (dyad) to different-sized communities (small to large) of connected networked people working towards a common goal (i.e., learning goal). We note two groups of concepts important for in research in this area: the general and the theoretical and practice-related. For the general concepts that are sociocultural, they include discourse, identity and new literacies.

*Discourse.* There are many ways in which discourse is sociocultural. It is sociocultural since it can refer to communication/interactions that are written or spoken, to ways of thinking that is mediated through language. Gee (1999) expands these understandings of communication/interactions to discourse, which includes not only language use but also action, interactions, values, beliefs, symbols, objects, tools and places. Generally, discourses are considered to shape and frame what is learned and can be learned. It can also shape and transform identities.

*Identity.* By identity, the trend in the learning sciences is to understand it to involve the interplay of the individual and the social. The

individual aspect refers to the person's definition of his self (who she or he is) often according to some personal attributes. The social aspect refers to the collective identity of larger social groups, such as a community. Collective identity can shape the definition of one's personal identity and personal identity can, in turn, shape the collective identity when the former is collectively shared and reproduced in the practices of daily life. This view is also supportive of the understanding that identity, be it personal or collective, is socially constructed and historically contingent as opposed to static and unchanging.

In other words, the idea of identity as socially constructed is central to the constructivist approach to learning. For example, it is through interaction and participation in a community that a person develops different identities or a sense of oneself as a learner. In the case of science learning, a student develops his identity as a science learner through involvement in specific activities and tasks related to experimentation in a Science classroom. Lave and Wenger (1991) suggest that in a learning community, there exists different identities of participation and that a person can experience a transformation of identity from a novice to an expert. How a student transforms himself and develops expertise in particular subject areas are important considerations in understanding student learning.

*New literacies.* Internet and social media brought by Web 2.0 participatory technologies (i.e., blogs, chats, wiki, social networking sites, etc.) have resulted in the emergence of new literacies (or new media literacy and digital literacy). It is suggested that this trend offers the possibility of cross-fertilisation between literacy and learning sciences communities (Palincsar & Ladewski, 2006) or disciplines as the literacy community incorporates new evolving technologies into their theory and practices. The new literacies differ from the traditional literacy of reading and writing based on printed text. Given the constantly changing nature of technology and the continual reshaping of literacy, Palincsar and Dalton (2005) have put forward the notion of "adaptive literacy". In relation to the new literacies, it is noted that students will need to be equipped with new competencies, skills, strategies and disposition (Palincsar & Ladewski, 2006).

The other main concepts refer to the specific theoretical and practice-related (interventionist) concepts that include pedagogical approaches such as the following:

*Computer-supported Collaborative Learning (CSCL).* CSCL is an emerging discipline in the learning sciences which integrates technology and collaboration for the purpose of building knowledge and learning. It is informed by a view of knowledge creation as the outcome of learners interacting with each other, sharing knowledge and building knowledge as a group or community. CSCL is concerned with the "practices of meaning making in the context of joint activity and the ways in which these practices are mediated through designed artefacts" (Koschmann, 2002, p. 20). Designed artefacts refer to learning materials or a particular technology. As a techno-pedagogical approach, CSCL is researched in different ways. One way involves the study of collaborative meaning-making mediated by technology at the micro-level (i.e., in the classroom) to determine how learning is accomplished through such interactions. Another line of research is focused on the design of technology and learning environments in all its aspects (DBR) to facilitate collaborative knowledge building. In yet another line of research such as experimental approach, it studies the influence of learning on a particular technological application in a controlled experimental situation.

*Knowledge Building (KB).* KB is a special form of CSCL with a similar focus on learning through the collaborative and cumulative building of knowledge by members of a community. KB is a techno-pedagogical approach developed by Bereiter and Scardamalia (2006). They situate their work theoretically against the backdrop of societies moving towards knowledge innovation and creation and the development of desired civilisational goals related to the idea of sustained knowledge advancement as essential for progress of all kinds and for solution to societal problems. KB is based on the notion of idea improvement in which the products of individual and collective meaning-making, such as ideas and artefacts, are made visible (and public) through material or technological means, such as the *Knowledge Forum* software. KB is also based on the idea of epistemic agency meaning that students co-construct and build knowledge in much the same way as original inventors/scientists engaging with similar questions.

This discussion of sociocultural concepts are interrelated in that they are concepts and theories used to conceptualise the interactive and collaborative nature of learning and, thus, terms, such as meaning-making, sense-making, conceptual change, take on a sociocultural cast which is a distinctive trend in the learning sciences.

### *Trend two: Systemic/organisation aspects of learning*

In addition to this interplay of the individual and the sociocultural aspects, the other main trend is the focus on systemic or organisational aspects on learning. These include the following relevant terms.

*Teacher development and learning.* On teacher development, it is well recognised that the teacher plays an important role in implementing educational changes. Research in the learning sciences on teacher learning tends to be embedded in interventionist studies in which teacher learning is incorporated into the researcher's design to facilitate implementation of a curriculum innovation. However, Fishman and Davis (2006) note that teacher learning is emerging as an important focus in the learning sciences and that there are synergistic opportunities for the learning sciences to engage with the prolific area of research on teacher learning (teacher education and teacher professional development). This is because both research on teacher learning and the learning sciences share socio-constructivist, situated-learning principles (2006). With regard to this, there is some agreement that teacher-centred approaches are more effective and sustainable models of teacher learning rather than expert-centric models in which experts pass information to teacher learners. In the teacher-centric model, teachers have a role in their own learning that can take the form of social action research and the development of learning communities in and across schools.

*Technology-enhanced learning (TEL).* While studies on TEL continue to grow and diverge in terms of their pedagogical or technological approaches (as seen in this section—e.g., CSCL, KB, social media for learning), there are scholars who are inquiring about the general and fundamental issues of the role of technology in formal and informal learning settings, and their implications for teachers and learners. A shift of belief from "learning from technology" to "learning with technology"

(e.g., Reeves, 1997) has prompted David Jonassen to propose the influential framework of "meaningful learning" (Howland, Jonassen, & Marra, 2012) which can be adopted as a guide for educators in designing TEL infrastructures and activities. The framework advocates that learning tasks are meaningful when they require intentional (goal-directed/regulatory), active (manipulative/observant), constructive (articulative/reflective), cooperative (collaborative/conversational), and authentic (complex/contextual) learning. Within such a perspective, the role of technology in learning should go beyond its functions as presentation, reference, communication or productivity tools to become cognitive tools or mindtools. As defined by Jonassen (2000), mindtools are computer-based tools and learning environments that have been adapted to function as intellectual partners with the learner in order to facilitate critical thinking and higher-order learning.

Other areas to consider are the critical success factors, models and challenges of integrating technologies into schools. For example, Mishra and Koehler (2006) articulated a model of Technological Pedagogical Content Knowledge (TPACK) that focused on what teachers ought to know about integrating technology in their instructions. The model can be applied to analyse individual teachers' professional growths as well as inform the designs of teachers' professional development programmes.

*Learning across boundaries and seamless learning.* There has been a growing interest within the learning sciences community in seeing and studying learning as an incessant activity across boundaries of space, time and curriculum (Van't Hooft & McNeal, 2010). Learning across boundaries, rather than just confining to formal school learning, is considered important in preparing students for all the skills and knowledge they will need for lifelong learning. Henceforth, student learning should develop the capacity to learn anytime and anywhere (Chen, Seow, So, Toh, & Looi, 2010).

Relevant to this notion are the studies in the field of mobile-assisted seamless learning. In a major international synthesis of 1:1 TEL, 17 international scholars (Chan et al., 2006) defined seamless learning as a learning style where a learner can learn in a variety of scenarios

and in which they can switch from one learning space (formal and informal learning, personal and social learning, learning in physical and digital worlds, etc.) to another easily and quickly, enabled by 1:1 (one-mobile-device-or-more-per-learner), 24x7 (24 hours a day, 7 days a week) settings. The exposition of such a learning approach has since led to a flurry of subsequent relevant discussions and studies within the research community with varied emphases (either on pedagogical designs, technological solutions or learners' autonomous learning experiences; Wong, 2012; Wong & Looi, 2011); thus, enriching the notion and bringing it closer to the heart of practice and translations.

*Translation and scaling up.* Scaling up involves adapting an innovation that is successful in one setting to be effectively used in a wide range of contexts. In contrast to similar efforts in other sectors of society, scaling up successful programmes has proven very difficult in education (Dede, Honan, & Peters, 2005). An innovative teaching or learning strategy that is successful with one practitioner often is difficult to generalise even to other instructors in the school, let alone to a broad range of practitioners. Scalable designs for educational transformation must avoid the "replica trap" (Wiske & Perkins, 2005): the erroneous strategy of assuming that there exists "one-size-fits-all" interventional methods and trying to repeat everything that worked locally, without taking into account the local variations, needs and environments.

In turn, scaling up has become a line of study of its own within the learning sciences community. Coburn (2003) defined "scale" as encompassing four interrelated dimensions: depth (deep and consequential change in classroom practices), sustainability (maintaining these changes over substantial periods of time), spread (diffusion of the innovation to large numbers of classrooms and schools), and shift in reform ownership (districts, schools and teachers to assume ownership of innovation). Dede and Wirth (2006) proposed an analogical conceptual framework (by associating with the biological ecosystem) to inform studies of scaling up innovations in education. Considering the complexity and interplay of multiple dimensions of educational reform, researchers have been repeatedly advocating a systemic change aspect that includes micro, meso and macro levels of education systems (Chan, 2011; Looi, So, Toh, & Chen, 2011; Owston, 2007).

In short, we have presented theoretical trends and important concepts in international development of learning sciences. We posit the importance of the interplay of individual and sociocultural, and systematic aspects as trends in the learning sciences and have introduced some important concepts that reflect these international trends.

## Section 3: Local Research Efforts in the Learning Sciences

Since the past decade, Singapore has introduced policies and initiatives to facilitate educational reforms to align with the developments of the 21st century, knowledge-based economy. Some important initiatives include the notions of *Teach Less, Learn More* and ability-driven education which are embedded within the thrusts of the ICT Masterplans in Education. A common objective of these initiatives is to address the limitations of predominant classroom practices which tend to be didactic and teacher centric. Indeed, as Looi, Hung and Tan (2005) noted, Singapore schools typically face the following challenges: (1) students do not think deeply; (2) teachers' and school leaders' beliefs about teaching and learning are not innovative and enterprising; (3) alternative pedagogical models are not readily available; (4) current assessment modes are not ideal for deep learning; and (5) ICT has not been meaningfully used within the schooling ecology.

To address the above-stated issues and to facilitate the translation of the Ministry of Education, Singapore's (MOE) policies into practice, NIE set up the Learning Sciences Lab (LSL) in 2005. LSL researchers embarked on a journey to understand the kinds of 21st century skills, competencies and dispositions that are needed for Singapore students to develop deep conceptual understanding and to understand how deep, engaged and meaningful learning occurs. In doing so, researchers would gain knowledge of how to design for deep learning (Looi, Hung, Bopry, & Koh, 2004). Through a continuous spiral of experimentation (i.e., DBR; see Section 1), school leaders, teachers and students will be involved in and exposed to workable ideas and developed point-at-able models. Their engagement in such experiences could transform mind-sets towards deep learning, autonomous learning and lifelong learning.

In his address to MOE regarding the initiative on FutureSchools (prototype schools), John Seely Brown emphasised that in order to create the types of schools needed for the 21st century, the necessary changes are not technological nor even pedagogical, but, rather, epistemological (22 August 2007, personal conversation). Educating for the Knowledge Age requires changing not merely the practices of education but the very conceptions that underlie those practices. It is for this reason that LSL positions itself at the intersection of student learning, teacher learning/pedagogy and designed activities/environments within institutional and systemic contexts. In this way, LSL is able to foster the kinds of changes that are needed for multiple levels if we are to move toward creating models of 21st century learning and teaching.

Indeed, in the 7 years since LSL's establishment, the Lab has gradually developed her research strengths and established international research networks, which has earned herself worldwide academic recognition. By the end of 2011, LSL researchers have been awarded 84 research projects. The majority of projects have been school-based, with most involving design partnerships with teachers and other stakeholders in the schools. To date, LSL has engaged over 85 schools and impacted over 500 teachers and over 10,000 students (LSL, 2011).

As there is considerable variation in the Lab's 7-year project portfolio, different ways of categorising research strands, either predefined by the management or emergent through members' consolidations, were proposed at different times in its history. In this Working Paper, a categorisation which was largely based on the natures of the designed learning interventions in respective projects was adopted. Five categories were identified, namely, (1) modelling and student-generated designs; (2) game-based learning; (3) mobile learning; (4) new media and learning; and (5) teachers' professional development (PD).

It is important to note that this categorisation is not definitive but merely offers readers a synoptic view of the Lab's past and present research. This is the case since a particular project may span across multiple categories or projects in the same category may be investigating a diverse range of research issues. In addition, this categorisation may look different from our categorisation of the two-decade learning

sciences research at the international level, as presented in Section 2. This is because LSL's studies have been predominantly interventionist-driven—that is, the main focus is on Learning Designs. The philosophical and systemic aspects are usually not the fundamental research inquiries but instead serve as the overarching frameworks (e.g., sense/meaning-making, representations, CSCL) that inform the researchers in their learning designs, or are embedded project tasks (e.g., teachers' PD) or subsequent phases (e.g., scaling up) of the design enactments. In the following descriptions, we will attempt to map the salient nature of each category to the most relevant research themes in the international level.

### *Modelling and student-generated designs*

Informed by socio-constructivism, many LSL studies seek to design learning activities that go beyond transmitting canonical representations of knowledge and concepts to the students. Instead, the focus is on facilitating/supporting students in generating multiple solutions or in making meaning, both individually and collaboratively. The rich and perhaps diversified ideas or designs could then serve as meaningful resources to stimulate learning reflections, analysis and synthesis, and "rise above" among the students. Through such learning activities, students not only learn about the subject matter, but also come to understand the means for working with and creating knowledge—finding problems, locating resources, testing ideas through experimentation, developing skills in argumentation and critique of various perspectives, applications of knowledge in real-life settings, and so on. These are the crucial skills to develop for autonomous (self-directed) and collaborative learning.

Key LSL studies that fall into this category are Productive Failure (for Math and Science learning; Kapur, 2008), *Ideas First* (for Science learning based on the KB approach; Bielaczyc & Ow, 2010), *GroupScribbles* (for Language, Math and Science learning; Looi, Chen, & Ng, 2010), Modeling and Visualisation Technology Enhanced Inquiry-based Science Learning (iMVT; for Science learning; Zhang, Ye, Foong, & Chia, 2010), Generative Activities in Singapore (GenSing; for Math learning; Davis, 2010), and Youth Tell (digital storytelling). In addition, the "informant design" approach was adopted in *Voyage* to

the *Age of Dinosaurs* (VAD, for Geography learning; Kim, Pang, Kim, & Lee, 2009), where students and teachers were closely involved in the co-design of the virtual reality educational game. Furthermore (and in a loose sense), the emergent student-generated design principle has virtually become the overarching principle of almost all other interventionist studies pervading the rest of the categories as explicated in the next few sub-sections.

### *Game-based learning*

Game-based learning has gained substantial worldwide attention since 2003. At LSL, research in game-based learning assumes two overlapping paths. In the first, gaming offers a conceptual practice with outcomes that enable learners to gain general skills needed specifically in an information-based culture (e.g., decision making, leadership, innovation and problem solving). The second path finds relevance in specific gaming content that helps the learner gain a fresh perspective on material and can potentially engage them in that content in more complex and nuanced ways (Johnson, Smith, Willis, Levine, & Haywood, 2011).

At LSL, several game-based learning projects, typically positioned at the intersection of the above-stated research paths, have been conducted. The overarching goal of their research is to advance game-based learning for the development of new literacies and 21st century competencies in formal and non-formal learning contexts. Examples include *StateCraft X* (National Education; Chee, Gwee, & Tan, 2011), *Legends of Alkhimia* (Chemistry; Jan, Chee, & Tan, 2010a), *Ideal Force* (Physics; Chee, Liu, & Hong, 2006), and *Chinese-PP* (Chinese Language; Wong et al., 2011). In a related note, the *Glocalizing Quest Atlantis* project (Zuiker, 2010), involving a collaboration with Indiana University that seeks to design “Uniquely Singaporean” missions (related to Geography learning) in a virtual environment for classrooms to literally play with academic concepts.

### *Mobile learning*

With the proliferation of increasingly affordable handheld devices, these devices continue to merit close attention as an emerging technology for teaching and learning. Mobile learning is distinguished from other forms

of learning in that: (1) learners learn across spaces as they take ideas and learning resources obtained in one location and apply or develop them in another; (2) learners learn across time by revisiting knowledge acquired earlier in a different context, which provides a framework for lifelong learning; and (3) learners move from topic by topic by managing a range of personal learning interests rather than adhering to a single curriculum (Sharples, Taylor, & Vavoula, 2007). Such habits of mind in learning would be able to complement the crucial but limited (in terms of class hours and teaching resources, among others) school-based formal education. Henceforth, the powerful features of mobile technology as an enabler and enhancer of personalised learning have become the fundamental rationale of the Lab's mobile learning research teams' focus on mobile-assisted seamless learning (see Section 2: "Learning across boundaries").

Several studies informed by this learning notion have been carried out, namely, the SEAMLESS project (for Science and English learning; Looi et al., 2010), *Move, Idioms!* (Wong, Chin, Tan, & Liu, 2010) and *MyCLOUD* (both for Chinese Language; Wong, Chai, Chin, Hsieh, & Liu, 2012), and mobile trails for in-situ knowledge building (for Geography and National Education; So, Tan, & Tay, 2012). Within NIE, a longitudinal ethnographic study on pre-service teachers' usage of laptops (in 1:1, 24x7 basis) in their coursework has also been conducted (Chen & Lee, 2011).

Moving on, the Lab's mobile learning research teams will seek to expand their studies to incorporate learning models, social media and augmented reality into their seamless learning interventions and practices. Another potential research direction is the in-depth ethnographic study of mobile-assisted seamless learner's self-regulation (or self-directed-*ness)* and their relationships with mobile devices (e.g., analysis of the patterns of self-initiated device usage for learning purposes, from the learners' perspective). Such research findings may inform the future enhancement of learning interventions.

### *New media and learning*

LSL's inquiry in new media and learning seeks to transform learning practices in and out of schools by fostering participatory learning

cultures (Jenkins, Purushotoma, Clinton, Weigel, & Robison, 2009) with new media. In a participatory learning culture, knowledge is socially constructed and, therefore, learning is constructed via meaningful social participation.

The Participatory Visual Culture project is LSL's first attempt in exploring visual thinking and visual culture using a DBR approach. It designs digital production tools and online community in order to create new learning spaces for new literacies. With the digital revolution, there is a significant shift from textual literacies to hybrid and visual literacies outside of schools. Most Singapore youths are on Facebook, Twitter, YouTube and other online social media, but schools have yet to leverage social media and digital production tools for youths to become critical media consumers and creative producers.

The Participatory Visual Culture project explores (1) how to design a social platform that can engage youths in visual communications and productions, and (2) how to design meaningful learning activities in either formal (school-related) or informal (out-of-school) settings. Meanwhile, the Six Learnings project (Lim, 2009) seeks to develop a common curricular design framework and translation principles for learning in virtual reality environments such as *Second Life.*

### *Teacher development and learning*

Recognising in-service teachers' pivotal roles in the meaningful use and integration of ICT in classroom teaching and learning, especially for the purpose of translating and scaling up the innovative learning designs, LSL researchers and their counterparts elsewhere have undertaken studies to shift teachers' epistemological beliefs (i.e., beliefs about the nature of knowledge) and develop their capacities in facilitating teacher development and learning (TEL). Three such studies are Spaces for Teachers' Explorations into Pedagogy (STEP), Teachers' Meaning-making Using Video for Examining Technology Integrated Practices (Lossman & So, 2010), and a tri-party (teacher-researcher-authority) collaborative inquiry programme (to investigate innovative strategies for the use of technology in Chinese Language classes; Wong, Gao, Chai, & Chin, 2011).

Looking forward, there may be less standalone projects in this area to be carried out by LSL in order not to overlap with studies of similar themes on teacher development and learning being conducted by other Academic Groups within NIE. Instead, teachers' PD activities have been more well-embedded into LSL's school-based interventionist studies in general, which will allow researchers opportunities to analyse teacher learning processes and distilling principles or models to advance future PD programmes.

All the above stated studies exemplify how research in LSL has deepened understanding on how to create the shifts in beliefs about teaching and learning within the formal schooling ecology as well as individual learners' out-of-school, autonomous learning cultures.

Table 2 depicts the major international research paradigms (as presented in Section 2) that inform individual areas of LSL research in the past 7 years (i.e., where LSL researchers prominently and explicitly relate their work to prior international research outcomes).

Again, the mappings presented in this table are not definitive—the emphases of the research inquiries may vary across projects and over time. In the *LSL Research Findings Report* (LSL, 2011), the Lab identified three major areas of contributions based on a synthesis of their repertoire of studies. The findings are summarised below.

1. The creation of participatory cultures and the development of design principles (not learning packages), with three meta-design principles being distilled:
   - designing complex, open-ended, authentic, disciplinary tasks;
   - designing for collaboration; and
   - setting/building appropriate socio-disciplinary and epistemic norms and practices.
2. Advancing understanding of student learning in the 21st century, with the following outcomes being achieved:
   - making models of complex natural phenomena (i.e., Science, Geography, Math);
   - collaborative interactions and working with multiple perspectives to advance learners' understanding;

Table 2. The mappings of LSL research areas to the major international research paradigms.

| | Modelling & student-generated designs | Game-based learning | Mobile learning | New media and learning | Teacher development and learning |
|---|---|---|---|---|---|
| Sense/meaning making | † | † | † | | |
| Representations | † | † | | | |
| Conceptual change | † | † | † | | † |
| Inquiry learning | † | † | † | | |
| Higher-order thinking | † | † | † | † | † |
| Self-regulated learning | | † | † | † | |
| Discourse | † | † | | † | † |
| Identity | | † | † | † | † |
| New literacies | | † | † | † | † |
| CSCL | † | † | † | † | † |
| Knowledge building | † | | † | | † |
| Teacher development | † | | | | † |
| TEL | † | † | † | † | † |
| Learning across boundaries | | † | † | | |
| Translation & scaling up | † | | † | | † |

- role playing, digital literacy and participation in new media ecologies;
- self-directed learning and learning how to learn;
- learning across the boundaries of formal and informal settings;
- multiple literacies and modalities; and
- enacting societal values through embodiment in virtual learning worlds.

3. Advancing understanding of teacher learning in the 21st century, including:
   - necessary types of pedagogical moves, such as empowering students to take ownership in their learning;
   - cultivating professional learning communities that operate as communities of inquiry among teachers; and
   - building a culture of trust among teachers and other educational stakeholders in order to support changes in teaching and learning practices.

Beyond LSL, many other research teams within NIE or other tertiary institutions have been carrying out education research studies whose topics of inquiry and/or research methodologies somewhat resemble those in the learning sciences field. However, not all of the researchers involved in such studies have identified themselves as learning scientists. According to a content analysis of publications in selected academic journals from 1997 to 2010, Singapore has been one of the six countries within the Asia-Pacific Region to have the most active learning sciences research contributions (Tan, Chai, Tsai, Lim, & Chou, 2012). In particular, Singapore and Hong Kong saw a steady growth in contribution of journal papers in the past 14 years (Tan & Lim, 2012). One example of local learning sciences-oriented studies conducted elsewhere is online argumentation in Science classroom (Chin & Osborne, 2010), which was conducted by Natural Science and Science Education Academic Group at NIE.

In addition, recognising the limitations of the conventional quasi-experimental (i.e., experimental group-control group design) and action research methodologies, an increasing number of local researchers who are carrying out learning intervention studies have adopted the approach of DBR. The DBR approach is seen as appropriate in

creating conducive conditions for eventual translation and scaling up of their innovations. One particular example is the Singapore Centre for Chinese Language—the DBR methodology was introduced to the Centre through their collaboration with LSL in mobile-assisted Chinese Language learning studies (Wong et al., 2010; Wong et al., 2012), thus influencing a few other internal project teams within the Centre to adopt DBR when conducting their studies in Chinese learning pedagogies.

## Section 4: Trend Analysis and Recommendations

Since its inception some 30 years ago, the learning sciences field has expanded into niche research areas (e.g., Sawyer, 2006) and the debate about its central tenets will carry on. What holds still is its commitment to transform practices with (1) new perspectives on learning, (2) design frameworks, (3) innovative technologies and pedagogies, and (4) ways to understand, carry out and sustain practices. Such understanding is vital for making policies. The trends of the field as summarised in Sections 2 and 3 share these common goals.

In providing solutions to 21st century demands, its cognitive and sociocultural orientation address the limitations from behaviourist and instructionist views on education. Nevertheless, this does not mean that learning scientists ignore the legacy coming from other educational paradigms. In integrating cognitive and sociocultural lenses on learning, the learning sciences field view precedent research paradigms, such as behaviourism and instructionism, as alternative and complimentary lenses on learning with different set of limitations.

The research in the learning sciences have also been enhanced through its fruitful conversations with other disciplines, such as sociology, psychology, domain-specific learning theories, linguistics, neuroscience and computer science, among others. The motivation is to pool knowledge across the various forms of expertise to advance human understanding in learning. That makes it a truly multi-disciplinary field (and that explains the use of plural form of “science” in “learning sciences”). This cross-disciplinary synthesising with a focus on learning which is the heart of the learning sciences brings together diverse strands from various disciplines to a single focus which can be very generative of new theories.

The DBR methodology continues to gain momentum and is beginning to spread beyond the learning sciences community. The proliferation of DBR reflects education researchers' increasing awareness of the fact that the many influences on learning operate at different levels, from neurons to individuals to schools to neighbourhoods to countries. DBR aims to "design thinking" as well as "design practice", taking into consideration the inevitable needs of integrating these levels and making sense of their respective relationships with learning. These issues are indeed essential to recent endeavours carried out in many countries and regions to bridge the gap between educational research and practice, with the aim of encouraging and supporting practitioners to adopt and adapt researchers' innovations into their daily ecology of use (Wong & Ogata, 2012).

Meanwhile, in order to nurture a critical mass of learning scientists with different orientations, an increasing number of universities in different parts of the world have been offering undergraduate or graduate programmes which are specialised in the field of study. Examples of such universities are Carnegie Mellon University, Stanford University, UC-Berkeley, National University of Ireland, Ludwig Maximilian University of Munich, Open University of the Netherlands, University of Nottingham, University of Sydney, and University of Malaysia Sarawak (UNIMAS), to name a few. Other academic programmes have instead scoped their curricula to combine the fields of learning sciences and TEL, under the name "learning sciences and technologies". Nevertheless, these academic departments or programmes tend to place greater emphasis on technology rather than the learning sciences.

The development of the learning sciences field continues to show promise and encounter challenges within Singapore. Next, we present five recommendations for advancing the field and bridging the gap between academics (theory) and practice in the Singapore context.

### *Emphasis on informal learning and the interplay with formal learning*

Greater effort should be put into studies on informal learning, and the interplay of formal and informal learning (i.e., not constrained by school culture). So far, research in Singapore is heavily focused on

learning that takes place in formal (school-based) settings. Though it is critical to understand how to transform learning practices within the social, cultural and structural constraints in schools, studying and designing learning in out-of-school settings are no less crucial. Out-of-school learning contexts, such as online social media, summer camps, museums, art centres, and learners' homes and neighbourhoods, are all sites with great potential for learning-in-contexts. Investigating and designing informal (not constrained by formal education) learning, culture provide great opportunities to transform learning without having to deal with the social, cultural and structural constraints of schooling.

### *Going beyond content mastery studies*

Identities, beliefs and values, among others, should take a much more central role in learning when we view learning as an enculturation process with guided participation. Through design, we may engage students in taking on professional identities (such as environmental scientists) as a way to help young people capture not only the situated-domain knowledge, but also the belief and value system not separable from the domain knowledge.

### *Promoting DBR and qualitative research methodologies*

DBR and many qualitative research methodologies are tools being developed to understand and transform practices. These research methodologies assume very different worldviews and realities. Research methodologies developed to understand the physical realities are often not appropriate or directly applicable for the study of human beings, social interactions, cultures and values. It is critical that we continue to develop researches that are humanistic in nature.

### *Negotiation of roles for researchers when scaling up*

Though learning scientists are inspired to work towards translation and scaling up of their learning designs, the negotiation of researchers' roles in the actual scaling up efforts (upon the completion of their studies) need to be carried out. Should they be merely playing the roles of consultants, or drivers of such efforts? Can they juggle with both their academic careers and commitments in supporting such (perhaps managerial) efforts? What kinds of support from various stakeholders should they be given?

### *More studies on systemic changes in meso/macro levels*

Reducing a complex individual learning phenomenon and group learning practices as controllable variables in a highly controlled learning context is a common research orientation in education. Although there is still a need to employ research methodologies of this nature as an inquiry approach, the research findings are often not applicable to real world practices. Education inquiries framed by a polar question (i.e., yes-no question) are insufficient in answering questions about social interactions, cultures, activities and practices. If the research goal were to transform the education system/paradigm, there is a need to expand the repertoire for research. Research methodologies that can be used to *understand* and *design* complex systems (such as classroom activities, schooling and online learning communities) should be prioritised. Without systematic understanding, educational reform can become a piecemeal effort without real world impacts.

## Conclusion

In short, the inauguration and flourishing of the learning sciences discipline since two decades ago can be seen as a timely reaction of education researchers to the unprecedented and highly demanding challenges of the 21st century economy and society. As the 21st century demand is an unprecedented global challenge, new research framing, directions, inquiries, methodologies and tools are developed, with ever stronger emphasis on bridging research and education practice, especially on reforming and transforming learning ecology and learning culture. With practices in mind, the learning sciences community seeks to "develop *new* solutions to solve *new* problems". As an emerging discipline, the learning sciences field is still evolving to accommodate itself to the changes of the world.

## References

Barab, S., & Squire, K. (2004). Design-based research: Putting a stake in the ground. *Journal of the Learning Sciences, 13(*1), 1–14.

Bielaczyc, K., & Ow, J. (2010). Making knowledge building moves: Toward cultivating knowledge building communities in classrooms. *Proceedings of the the international conference of the learning sciences* (pp. 865–872), Chicago, MA: International Society of the Learning Sciences.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How people learn: Brain, mind, experience and school.* Washington, DC: National Academy Press.

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *Journal of the Learning Sciences, 2*(2), 141–178.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32–42.

Chan, C. K. K. (2011). Bridging research and practice: Implementing and sustaining knowledge building in Hong Kong classrooms. *International Journal of Computer-Supported Collaborative Learning, 6*(2), 147–186.

Chan, T.-W., Roschelle, J., Hsi, S., Kinshuk, Sharples, M., Brown, T., … Norris, C. (2006). One-to-one technology-enhanced learning: An opportunity for global research collaboration. *Research and Practice in Technology-Enhanced Learning, 1*(1), 3–29.

Chee, Y. S., Gwee, S., & Tan, E. M. (2011). Learning to become citizens by enacting governorship in the *Statecraft* curriculum: An evaluation of learning outcomes. *International Journal of Gaming and Computer-Mediated Simulations, 3(*2), 1–27.

Chee, Y. S., Liu, Y., & Hong, K. S. (2006). Weaving pedagogy into gaming: Learning design principles for developers. *Proceedings of the International Conference on Computers in Education* (pp. 495–498). Beijing, China: Asia-Pacific Society for Computers in Education.

Chen, W., & Lee, C. (2011). From device centric to people centric ubiquitous computing: Pre-service teachers using technology across spaces. *Proceedings of the 19th International Conference on Computers in Education* (pp. 547–554). Chiang Mai, Thailand: Asia-Pacific Society for Computers in Education.

Chen, W., Seow, P., So, H.-J., Toh, Y., & Looi, C.-K. (2010). Extending students' learning spaces: Technology-supported seamless learning. *Proceedings of the International Conference of the Learning Sciences 2010* (pp. 484–491), Chicago, IL: International Society of the Learning Sciences.

Chin, C., & Osborne, J. (2010). Supporting online argumentation through students' questions: Case studies in science classroom. *Journal of the Learning Sciences, 19*(2), 230–284.

Coburn, C. (2003). Rethinking scale: Moving beyond numbers of deep and lasting change. *Educational Researcher, 32*(6), 3–12.

Cole, M. (1996). *Cultural psychology: A once and future discipline.* Cambridge, MA: Harvard University Press.

Cole, M., Engestrom, Y., & Vasquez, O. (1997). *Mind, culture, and activity: Seminal papers from the laboratory of comparative human cognition.* New York, NY: Cambridge University Press.

Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design research: Theoretical and methodological issues. *Learning Sciences, 13*(1), 15–42.

Davis, S. M. (2010). Generative activities: Making sense of 1098 functions. In R. Less, C. R. Haines, P. L. Galbraith & A. Hurford (Eds.), *Modeling students' mathematical modeling competencies* (Vol. 5, pp. 189–198). New York, NY: Springer.

Dede, C., Honan, J., & Peters, L. (Eds.). (2005). *Scaling up succes: Lessons learned from technology-based educational improvement.* New York, NY: Jossey-Bass.

Dede, C., & Wirth, T. E. (2006). Scaling up: Evolving innovations beyond ideal settings to challenging contexts of practice. In K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 551–566). Cambridge, MA: Cambridge University Press.

Fishman, B., & Davis, E. (2006). Teacher learning research and the learning sciences. In K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 535–550). Cambridge, MA: Cambridge University Press.

Friedman, T. L. (2005). *The world is flat: A brief history of the twenty-first century.* New York, NY: Farrar, Straus & Giroux.

Gee, J. P. (1999). *An introduction to discourse analysis: Theory and method.* New York, NY: Routledge.

Howland, J. L., Jonassen, D., & Marra, R. M. (2012). *Meaningful learning with technology.* New York, NY: Pearson Higher Education.

Hutchins, E. (1995). *Cognition in the wild.* Cambridge, MA: MIT Press.

Jan, M., Chee, Y. S., & Tan, E. M. (2010a). Learning science via a science-in-the-making process: The design of a game-based learning curriculum. *Proceedings of the International Conference Onimmersive Technologies for Learning* (pp. 13–25). UK: Iverg Publishing.

Jan, M., Chee, Y. S., & Tan, E. M. (2010b). Unpacking the design process in design-based research. *Proceedings of the the 9th International Conference of the Learning Sciences* (Vol. 2, pp. 470–471). Chicago, IL: International Society of the Learning Sciences.

Jenkins, H., Purushotoma, R., Clinton, K. A., Weigel, M., & Robison, A. J. (2009). *Confronting the challenges of participatory culture: Media education for the 21st century.* Cambridge, MA: The MIT Press.

Johnson, L., Smith, R., Willis, H., Levine, A., & Haywood, K. (2011). *The 2011 horizon report.* Austin, TX: The New Media Consortium.

Jonassen, D. (2000). *Computers as mindtools for schools: Engaging critical thinking.* Upper Saddle River, NJ: Merrill.

Kapur, M. (2008). Productive failure. *Cognition and Instruction, 26*(3), 379–424.

Kim, B., Pang, A., Kim, M.-S., & Lee, J. (2009). Designing with learners for game-based collaborative learning: an account of T-rex group. *Proceedings of the International Conference on Computer Supported Collaborative*

*Learning* (pp. 120–122). Rhodes Island, Greece: International Society of the Learning Sciences.

Knight, L. A., & Pye, A. J. (2003). Learning across boundaries and change over time: The value of the notion of network learning. *Proceedings of the International Conference on Organizational Learning and Knowledge 2003.* Lancaster, UK: The Organizational Learning, Knowledge and Capabilities (OLKC) Community. Retrieved from http://www2.warwick.ac.uk/fac/soc/wbs/conf/olkc/archive/olk5/papers/paper28.pdf

Koschmann, T. (2002). Dewey's contributions to the foundations of CSCL research. *Proceedings of the International Conference on Computer Supported Collaborative Learning* (pp. 17–22), Boulder, CO: Asia-Pacific Society for Computers in Education.

Krathwohl, D. R. (2002). A revision of Bloom's Taxonomy: An overview. *Theory into Practice, 41*(4), 212–218.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation.* Cambridge, UK: Cambridge University Press.

Lim, K. Y. T. (2009). The six learnings of *Second Life*: A framework for designing curricular interventions in-world. *Journal of Virtual Worlds Research, 2*(1), 12–18.

Learning Sciences Lab (LSL). (2011). *Learning Sciences Lab report on research 2005–2011.* Singapore: National Institute of Education, NTU.

Looi, C.-K., Chen, W., & Ng, F. K. (2010). Collaborative activities enabled by *GroupScribbles* (GS): An exploratory study of learning effectiveness. *Computers & Education, 54*(1), 14–26.

Looi, C.-K., Hung, D., Bopry, J., & Koh, T. S. (2004). Singapore's Learning Science Lab: Seeking transformations in ICT-enabled pedagogy. *Educational Technology Research and Development, 52*(4), 91–99.

Looi, C.-K., Hung, D., & Tan, S. C. (2005). A research agenda for fostering deep learning mediated by technologies. *Global Chinese Journal on Computers in Education, 4*(1–2), 85–100.

Looi, C.-K., Seow, P., Zhang, B. H., So, H.-J., Chen, W., & Wong, L.-H. (2010). Leveraging mobile technology for sustainable seamless learning: A research agenda. *British Journal of Educational Technology, 42*(1), 154–169.

Looi, C.-K., So, H.-J., Toh, Y., & Chen, W. (2011). The Singapore experience: Synergy of national policy, classroom practice and design research. *International Journal of Computer-Supported Collaborative Learning, 6*(1), 9–37.

Lossman, H., & So, H.-J. (2010). Toward pervasive knowledge building discourse: Analyzing online and offline discourses of primary science learning in Singapore. *Asia Pacific Education Review, 11(*2), 121–129.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for integrating technology in teacher knowledge. *Teachers College Record, 108(*6), 1017–1054.

Mumford, E. (2003). *Redesigning human systems.* Hershey, PA: IRP Press.

Owston, R. (2007). Contextual factors that sustain innovative pedagogical practice using technology: an international study. *Journal of Educational Change, 8*(1), 61–77.

Palincsar, A. S., & Dalton, B. (2005). Speaking literacy and learning to technology; Speaking technology to literacy and learning. In B. Maloch, J. Hoffman, D. Schallert, C. Fairbanks & J. Worthy (Eds.), *54th yearbook of the National Reading Conference* (pp. 83–102). Oak Creek, WI: National Reading Conference.

Palincsar, A. S., & Ladewski, B. (2006). Literacy and the learning sciences. In K. Sawyer (Ed.), *Handbook of the learning sciences* (pp. 299–317). Cambridge, MA: Cambridge University Press.

Reeves, T. C. (1997). A model of effective dimensions of interactive learning on the world wide web. *Proceedings of the Interaktiivinen Teknologia Koulutuksessa 1997* (pp. 23–31). Hameenlinna, Finland: Interaktiivinen Teknologia Koulutuksessa.

Robinson, K. (2010). Changing education paradigms. In RSA Animate, *YouTube*. Retrieved from http://www.youtube.com/watch?v=zDZFcDGpL4U.

Roschelle, J., Rafanan, K., Estrella, G., Nussbaum, M., & Claro, S. (2010). From handheld collaborative tool to effective classroom module: Embedding CSCL in a broader design framework. *Computers & Education, 55*(3), 1018–1026.

Sandoval, W. A., & Bell, P. (2004). Design-based research methods for studying learning in context: Introduction. *Educational Psychologist, 39*(4), 199–201.

Sawyer, K. (2006). Introduction: The new science of learning. In K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 1–18). Cambridge, MA: Cambridge University Press.

Scardamalia, M., & Bereiter, C. (2006). Knowledge building: Theory, pedagogy and technology. In K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 97–118). Cambridge, MA: Cambridge University Press.

Schraw, G., Crippen, K. J., & Hartley, K. (2006). Promoting self-regulation in science education: Metacognition aspart of a broader perspective on learning. *Research in Science Education, 36*(1–2), 111–139.

Sharples, M., Taylor, J., & Vavoula, G. (2007). A theory of learning for the mobile age. In R. Andrews & C. Haythornthwaite (Eds.), *The Sage handbook of e-learning research* (pp. 221–247). London, UK: SAGE.

Simon, H. A. (1969). *The sciences of the artificial.* Cambridge, MA: MIT Press.

So, H.-J., Tan, E., & Tay, J. (2012). Collaborative mobile learning in situ from knowledge building perspectives. *The Asia-Pacific Education Researcher, 21*(1), 51–62.

Tan, S. C., Chai, C.-S., Tsai, C.-C., Lim, C.-P., & Chou, C.-H. (2012). Learning sciences research in Asia Pacific countries from 1997 to 2010: A content

analysis of publications in selected journals. *The Asia-Pacific Education Researcher, 21*(1), 4–14.

Tan, S. C., & Lim, C.-P. (2012). Editorial: Learning sciences research in the Asia Pacific countries. *The Asia-Pacific Education Researcher, 21*(1), 1–3.

Van't Hooft, M., & McNeal, T. (2010). *Mobile phones for mobile learning: The Geo-historian project.* Paper presented at American Educational Research Association 2010, Denver, CO, USA. Retrieved from http://www.rcet.org /research/presentations/AERA_2010_geohistorian_vanthooft.pdf

Wiske, M. S., & Perkins, D. (2005). Dewey goes digital: Scaling up constructivist pedagogies and the promise of new technologies. In C. Dede, J. Honan & L. Peters (Eds.), *Scaling up success: Lessons learned from technology-based educational improvement* (pp. 27–47). New York, NY: Jossey-Bass.

Wong, L.-H. (2012). A learner-centric view of mobile seamless learning. *British Journal of Educational Technology, 43*(1), E19–E23.

Wong, L.-H., Boticki, I., Sun, J., & Looi, C.-K. (2011). Improving the scaffolds of a mobile-assisted Chinese character forming game via a design-based research cycle. *Computers in Human Behavior, 27*(5), 1783–1793.

Wong, L.-H., Chai, C.-S., Chin, C.-K., Hsieh, Y.-F., & Liu, M. (2012). Towards a seamless language learning framework mediated by the ubiquitous technology. *International Journal of Mobile Learning and Organisation, 6*(2), 156–171.

Wong, L.-H., Chin, C.-K., Tan, C.-L., & Liu, M. (2010). Students' personal and social meaning making in a Chinese idiom mobile learning environment. *Educational Technology & Society, 13*(4), 15–26.

Wong, L.-H., Gao, P., Chai, C.-S., & Chin, C.-K. (2011). Where research, practice and authority meet: A collaborative inquiry for development of technology-enhanced Chinese language curricula. *The Turkish Online Journal of Educational Technology, 10*(1), 232–243.

Wong, L.-H., & Looi, C.-K. (2011). What seams do we remove in mobile assisted seamless learning? A critical review of the literature. *Computers & Education, 57*(4), 2364–2381.

Wong, L.-H., & Ogata, H. (2012). Editorial: Technology transformed learning: Going beyond the one-to-one model? *International Journal of Mobile Learning and Organisation, 6*(2), 95–98.

Zhang, B., Ye, X., Foong, S. K., & Chia, P. (2010). Developing an iMVT pedagogy for science learning. *Proceedings of the the International Conference of the Learning Sciences* (pp. 360–361), Chicago, IL: International Society of the Learning Sciences.

Zuiker, S. J. (2010). Think global/design glocal. *Educational Technology, 50*(5), 37–40.

A publication of the
Office of Education Research,
NIE/NTU, Singapore © 2014

ISBN 978-981-07-9644-0

NIE
NATIONAL INSTITUTE OF EDUCATION
SINGAPORE

An Institute of

NANYANG TECHNOLOGICAL UNIVERSITY