OER KNOWLEDGE BITES

OER Symposium: Educating for Innovation

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Speakers *Michael Tan, Kenneth Lim, Wu Longkai, Loh Chin Ee*
Panel Chair *Dennis Kwek*

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About OER Knowledge Bites

Launched in May 2016 by the Office of Education Research at the National Institute of Education, Singapore, **OER Knowledge Bites** aims to share education research discussions and issues as seen in the Singapore context. It also serves as a platform for researchers to share thoughts and concepts of education research with policymakers, educators and the public.

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By *Dennis Kwek*

THE GAUNTLET HAS been thrown. In 2011, during his State of the Union Address, U.S. President Barack Obama told his nation and the world: "To win the future, America needs to out-educate, out-innovate, and out-build the rest of the world" (Obama, 2011). To do this, America began investing heavily in R&D, creating environments ripe for innovation and risk-taking, and investing in innovation education, or education that can create a generation of innovative citizens.

Why is it that a country, ranked 27th out of 34 Organisation for Economic Co-operation and Development (OECD) countries in the Programme for International Student Assessment (PISA) 2012 international benchmarks—17th position in reading, 20th in science, 27th in mathematics—is able to continue to be a key leader in innovation and innovative technologies? Likewise, how is it that Israel, that trails behind the USA and pales in comparison to Singapore that is in the top 3, is acknowledged as the Start Up Nation of the world (Senor & Singer, 2009)? Is there an inverse relationship between education and innovation? How can schooling encourage students to be more innovative, and through what means?

In Singapore, Acting Minister for Education (Schools) Mr Ng Chee Meng points out that a key area for MOE is to generate students who are "innovative, creative and risk-taking, even as they continue to excel as they have been doing" (Ng, 2015). He emphasises: "We need more innovators, inventors, path-blazers, people who can push the envelope, who can create value for society". Innovation is also a key priority for Acting Minister of Education (Higher Education and Skills) Mr Ong Ye Kung, who in the 2016 Committee of Supply Debate, highlighted that "mastery begets creativity and innovation" (Ong, 2016). There are two implications behind these statements. First, the challenge for Singapore moving ahead is to have both academic excellence (something that has pushed us to the forefront of international benchmarks), and the innovative spirit needed to fuel Singapore's future knowledge-based economy. Second, there is the question of whether students must acquire content mastery first before they can become innovative, or whether there is a more nuanced, dialectical relationship between content mastery and innovation. For example, research into innovative businesses such as Apple points to how innovations are often brew from interdisciplinary teams where the diversity of ideas and people help to create new innovations (Hewlett, Marshall & Sherbin, 2013).

> Is there an inverse relationship between education and innovation? How can schooling encourage students to be more innovative, and through what means?
>
> – Dennis Kwek,
> *Office of Education Research*

Beyond the formal schooling years, Singapore's innovation push is manifested through the Smart Nation Initiative. Coordinated by the Prime Minister's

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Office, the Smart Nation Initiative aims to generate infrastructures, policies, ecosystems and capacities for people, institutions, businesses and government to co-create innovative solutions that can have a strong social impact. On 22 May 2016, the Sunday Times newspaper documented that the Smart Nation initiative has made "reasonable progress in the past 18 months" (Chng, 2016). Over 18,000 new jobs are opening up for people skilled in ICT, cyber security, data science and data analytics. The Singapore's Infocomm Development Authority is at the forefront of this effort, with IDA Labs opening two community makerspaces to encourage and grow a Singaporean maker culture. Nineteen secondary schools will offer Programming at the O-Level Examination, and a cottage industry of coding tuition centres for kids has emerged around the island.

All these are responses to the global innovation wave, even as Barack Obama pumps over US$4 billion into the *Computer Science for All* initiative that aims to make computer science education available to all American students from kindergarten through high school (Smith, 2016). Universities are contributing to this innovation education endeavor as well. For example, the Massachusetts Institute of Technology Media Labs' Lifelong Kindergarten research group is generating innovative technologies and pedagogies that will enable children as young as 7 from all backgrounds to experience making, tinkering, and even app development through online communities.

What will it take for Singapore to win the future?

This Office of Education Research (OER) Symposium on Education for Innovation is the beginning of what we hope to be a series of discussions, dialogues and sharings around innovation education, drawing from the work that OER researchers are doing in innovation education, 21st Century Competencies, formal and informal learning, and linking it to international research in these areas. A key milestone for us will be the *Redesigning Pedagogy International Conference* in 2017, which will have a theme on creativity, innovation and values as we take up the innovation challenge from a research evidence base.

> This is the beginning of a longer dialogue around innovation education as we begin to examine and understand the indigenous nature of innovation, education and schooling in Singapore's context.
>
> – Dennis Kwek

There are two key aspects to innovation education. The first is about the capabilities required by young people to have a successful life, and to contribute to economic, social and individual well-being. The second is about what needs to be done to align the nature and structure of school with contemporary culture.

The speakers at the Symposium attempted to address these issues, focusing on pedagogical principles,

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case studies of students doing innovative work, the relationship between formal and informal learning, and the importance of design thinking. This is the beginning of a longer dialogue around innovation education as we begin to examine and understand the indigenous nature of innovation, education and schooling in Singapore's context, so that we may win the future for Singapore.

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About the Speaker

Dennis Kwek is a Research Scientist and Assistant Dean (Research Communications) in the Office of Education Research at the National Institute of Education, Singapore. His research interests include baseline research, system studies, school innovations, pedagogical research, classroom interactions, discourse analysis, qualitative methodology, educational philosophy, asian philosophy and pedagogies, and sociology of education.

Makerspaces in Singapore: Pedagogical Principles for Innovation

By *Michael Tan*

MAKERSPACES IN SINGAPORE have been closely associated with the movement to enhance design skills and innovativeness. In schools, this movement has been nascent, with only a handful of schools with actual physical makerspaces, and a slightly larger number with the intentions to develop one or are currently considering maker-type educational initiatives in informal settings. While these initiatives are to be commended, makerspaces need to be thought of as (cultural) technology that can be used or abused. If innovativeness as a core disposition is desired as an outcome for participation in makerspaces, three pedagogical principles are proposed, focussing on: (i) invention; (ii) people-centeredness; and (iii) just in time knowledge provision. I present supporting arguments for these principles and elaborate on their relationship to making in makerspaces.

Introduction

Makerspaces can be thought of as re-imagined engineering workshops, with equipment that supports digital fabrication and rapid prototyping technologies that represent the future for manufacturing processes. Among machines that have captured the public imagination are 3D printers and to a lesser extent, laser cutters and CNC (Computer Numerical Control) routers. These machines work by being fed a digitally created design, and perform manufacturing tasks to a high degree of precision without much human supervision. At the same time, integrated electronics components and computer processing power have become widely accessible, with open-sourced [1]Arduino boards providing easy ways to create objects with programmable interactivity and intelligence. With all these new technologies and numerous stories of apparently innovative uses in student projects, it can be easy to believe that innovation will inevitably occur as a result of participation in makerspace activity. This is not necessarily the case, however, as technologies in general have open affordances and didactic instructions can result in lower instructional outcomes. To circumvent this, it is important that educators have general principles to guide their instructions in makerspaces. If innovativeness is a prime goal of makerspace activity, it is important to understand the processes of innovation and to consider their pedagogical implications.

What Is Innovation?

Innovation, quite simply, shares much of its knowledge base with that of creativity. However, innovation has a particularly practical aspect to it.

[1]Arduino is an open-source electronics platform based on easy-to-use hardware and software. It is intended for anyone making interactive projects. https://www.arduino.cc/

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While creativity can be associated with, for example, works of visual art that are simply appreciated by others, innovativeness is also concerned with the practical applicability of ideas, especially by others who will make use of these creative ideas. As such, design knowledge provides much insight into the processes of innovation as the core concern of design is user-centric creative problem-solving. If we were to consider the design process, we see broadly the following steps: (a) a user needs an analysis phase; (b) an ideation phase; and (c) a prototyping and testing phase before final acceptance. While most of these steps are fairly straightforward, the "magic" happens when designers decide which of their numerous ideas is most appropriate for the problem. This process is termed abductive reasoning, and is identical to the process physicians use to determine the medical condition their patients are suffering from. Distinct from deductive reasoning whereby the deductive rule is absolute, in abductive reasoning uncertainty is tolerated. For instance, while a deductive rule could be phrased as "darkness is the absence of light", for which the occurrence of "darkness" *must* mean that "light is absent", an abductive rule could be phrased as "when the ground is wet, it usually means that it has rained". In the latter, with an observation of "wet ground", we cannot rule out "the gardener wet the ground". Therein lies the key challenge to innovativeness—the element of risk that accompanies the epistemic leap from perceived reality to the intended design intent. Innovators and creators can never be completely certain about the fit for purpose of their inventions, and this uncertainty is especially high for novices.

Pedagogical Implications

As a result of the epistemic risk-taking associated with innovation, it is important in instructional scenarios that learners are given opportunities to develop their abductive reasoning abilities, and that the psycho-social environment is designed to encourage risk-taking. In studies of design work, researchers have shown that collaborative efforts usually produce results of higher quality. In sum, if we wish to nurture innovativeness in learners, the following principles are to be advocated:

While creativity can be associated with, for example, works of visual art that are simply appreciated by others, innovativeness is also concerned with the practical applicability of ideas, especially by others who will make use of these creative ideas.

– Michael Tan,
Office of Education Research

Invent, Not Manufacture

The emphasis on makerspaces should be on getting learners to suggest solutions for design prompts. Here, instructors need to resist the temptation to deem their students' work as not "up to standard" of canonical solutions. A way to address this is through the principle of iterated prototyping—a

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standard practice for designers, whereby shortened cycles of development (sprints) are privileged over a single, effortful march through the typical time it would take to complete a unit. By privileging action and prototyping, instructors can lower the costs of failure and mistakes, and allow multiple chances for learners to improve their ideas.

People, Not Things

In makerspaces, the plethora of fanciful new objects, machines and tools means that it is highly tempting for instructors to focus their instruction on equipment use and expertise development. Instead, instructors should treat these objects as what they are—tools that are a means to an end—the more important end being the development of student learning and dispositions. Due to the interdisciplinary nature of design work, it will be useful to appoint disciplinary "experts" within teams to make sure they cover each other's blind spots. Instructors need to design classroom activity that nurtures interpersonal relationships too.

Just In Time, Not Just In Case

The conventional curriculum is provided as a means to ensure continuity of culture—students need to know these things so that we can continue our current way of life. However, this does not mean that the pedagogical approach needs to take on a similarly directed stance. Learning theories suggest that it is often more useful to get students to struggle through with material contexts first, in order to gain some grounded experience of phenomena, before introducing the formalisms that are part of the curriculum. This requires instructors to be aware of serendipitous moments when it would be especially timely to introduce pieces of knowledge relevant to the problem-solving process, and this can be hard to orchestrate. Nonetheless, this approach is superior to one where direct instruction is provided from the outset, and 'practical work' is done subsequently.

In makerspaces, the plethora of fanciful new objects, machines and tools means that it is highly tempting for instructors to focus their instruction on equipment use and expertise development. Instead, instructors should treat these objects as what they are—tools that are a means to an end—the more important end being the development of student learning and dispositions.

– Michael Tan

Conclusion

Innovativeness is most likely an innate disposition, which we learn to internalise from school that we do not. Along with the lack of opportunities to develop these dispositions while schools are too busy imparting wisdom, it is hardly surprising that innovative outcomes from schooling are rather poor. Steps must be taken in order to change this state of affairs. For one, acknowledging that

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innovation will definitely be accompanied by literal and metaphorical messes will be important. The process of innovation will often *appear* inefficient, with many failures, mistakes and missteps. However, these missteps are highly essential and will ultimately contribute to the eventual success. It is also important to consider deeply the end points of innovativeness as answers to the question "What is innovation for?" Considerable tension will be encountered between allowing open-ended innovation and innovation geared towards desired ends which needs to be carefully managed. Innovation remains the grand challenge of our times, and our schools need to rise up to meet it. With makerspaces and thoughtful implementation of instructional strategies, we will be better equipped to address these challenges.

About the Speaker

Michael Tan is a Research Scientist in the Office of Education Research at the National Institute of Education, Singapore. His research interests include curriculum studies, embodied embedded extended and enacted cognition, science education, and sociology of school knowledge

Makers on Parade: The Spontaneous Emergence of a Makerspace Within a School

By *Kenneth Y. T. Lim*

MAKERSPACES HAVE BEEN hailed as exemplars of community-led grassroots constructs. Their rise in several countries in the West has led to a renewed interest in reframing learning in terms of models akin to post-industrial apprenticeship. Across the Pacific, makerspaces have also emerged and/or attempted to be nurtured in countries such as South Korea, Thailand and Singapore. These recent developments encourage the study of the extent to which emergent community-driven initiatives cohere with more traditional conceptualisations of ordered civil society which, characterise much of East Asia. This paper describes one such enactment in a state-funded school in Singapore, in which the local makerspace emerged without any formal structuring from those who might be seen as the brokers of power and authority.

With regard to the study being introduced in this paper, the makerspace and its supporting maker culture is situated within a secondary school in Singapore. It operates in a way which transcends the boundaries of both the formal and non-formal curricula.

The National Cadet Corps (NCC) (Air) is a popular Co-Curricular Activity (CCA) across schools in Singapore, regardless of gender orientation. Among the activities it organises are site visits to airbases operated by the Republic of Singapore Air Force, so as to give the student-cadets a taste of such a career option. As such, the NCC (Air) curriculum—which is overseen by an officer from the Ministry of Education (who is known as the Commander NCC [Air])—has two main components: foot drills and aeromodelling. The student-cadets are permitted to specialise in one or the other.

To build a healthy sense of competition and esprit de corps across the various NCC (Air) units emplaced within schools in Singapore, annual Aeromodelling competitions are organised on an inter-school basis. Teams from the schools compete to pilot remote-controlled scale-model aircraft around circuits, in much the same way that professional aerobatic stunt pilots would do.

A corollary of the training as student-cadets prepare for such tournaments is that aircraft will crash and will need to be repaired or replaced. Each school-based NCC (Air) unit is given autonomy to craft the curricular enactments in order to best prepare the cadets to fly the aircraft skillfully. The NCC (Air) student-cadets have designed a scaffolded curriculum spanning the four years of secondary school. The novice trainees (typically aged 12 to 13) are introduced to the principles and concepts of flight through flight simulation software. They then progress to practicing on remote-controlled powered-kites, and finally to the scale-model aircraft.

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What distinguishes the student-cadets at this particular school from their counterparts from other schools in Singapore is that they have developed a strong "can do", or improvisational spirit within themselves, and this is primarily evident in how they approach the repair and tinkering of the design of the stock, off-the-shelf kites and model-aircraft which they fly.

Of equal interest is how some of the more senior student-members within the team have gone beyond just tinkering with the design of flying models, and have cannibalised parts to diversify into land-based, and even prototype water-based craft.

To elaborate, six of the senior student-members began to iterate designs and prototypes. A blueprint for an earlier design is shown on the following page.

In focus group discussions with the students, they described this initial design as follows:

"The RC Car V1's body was to have been made of wood. The car would have been propelled forward by the two motors driving its back wheels. The rotation of the wheels would depend on the plastic servo located at the front of the car. However, the RC Car V1 was not built as there were various safety concerns and budget issues."

The number of bespoke parts which would have been needed for their first iteration led them to look for possible sources to cannibalise. They described their thinking thus:

"The RC Car V2 was conceptualised and subsequently built but there is no image available as it was dismantled on the same day that it was constructed. The car's body was made of wood. The car was made with two sets of Cessna (aircraft) landing gears. It was intended to showcase how Cessna parts could be readapted to serve a different function as a demonstration of creativity."

> ...the maker culture that has spontaneously emerged within the NCC (Air) at this school finds enactions through seamlessly negotiating formal and non-formal structures of time and space within and without the schooling curriculum of an East Asian society more often associated with rules, laws, fines and regimented prescription.
>
> – Kenneth Y. T. Lim,
> *Office of Education Research*

"One of the landing gear was glued at the back of the car while the other landing gear was attached to a servo, allowing the car to turn. A motor was attached to the back of the car in order to propel the car forward."

The students also shared that during the course of their iterative attempts, they appropriated—with the permission and supervision of teachers—parts, materials, and machining tools from the school's metalworking workshop managed by the Design

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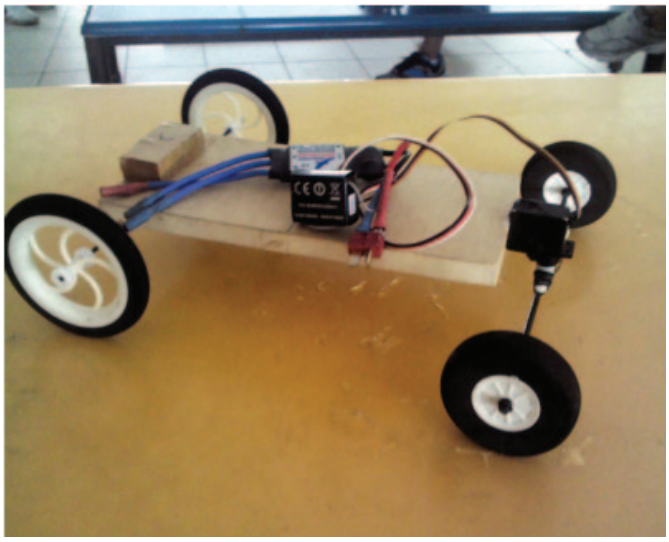
and Technology Department, even though they were not necessarily taking Design and Technology as an academic subject.

In fact, they went even further because in some cases, they found the soldering tools "not precise enough". In these cases, they leveraged their social capital with the proprietor of the local kite-supplier, to gain access to the more well-maintained and up-to-date tools found in the proprietor's personal workshop, even though the latter entailed a half-hour bus-journey beyond their local estate.

Of particular interest was that—as they continued iterating the design, and because they were personally invested in a task, which was both authentic and meaningful—the student-cadets gradually appropriated the epistemic frame of the designer and the engineer; thus, for example, they were able to describe a subsequent iteration of the go-kart:

> They are able to operate fluently across what might initially come across as hard boundaries because they derive meaning and authenticity from their membership and participation in interest-driven communities
>
> – Kenneth Y. T. Lim,

"The RC Car V3 reuses the same wooden car body used by RC Car V2. However, a major design alteration involves wheels connected by carbon rods



are used instead of the Cessna landing gear. This alteration was made to lower the centre of gravity so that the car would be more stable. A Karbonite servo was used to turn the wheels instead of a plastic servo as the plastic servo will vibrate the moment the wheels are attached."

In these and other ways, the maker culture that has spontaneously emerged within the NCC (Air) at this school finds enactions through seamlessly negotiating formal and non-formal structures of time and space within and without the schooling curriculum of an East Asian society more often associated with rules, laws, fines and regimented prescription. The study described in this paper suggests that the student-cadets are successfully able to negotiate both the formalised, regimental protocols of such settings as well as leverage—often informally through their own social networks—seemingly peripheral actors and structures such as kite-sellers, metal-working

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workshops and tools. They are able to operate fluently across what might initially come across as hard boundaries because they derive meaning and authenticity from their membership and participation in interest-driven communities—no one needs to tell them to persevere and improve, instead they engage in a complex series of performances encompassing goal-setting, resource-evaluation and self- and peer-assessment according to both personal and socially moderated standards.

About the Speaker

Kenneth Y. T. Lim is a Research Scientist in the Office of Education Research at the National Institute of Education, Singapore. His doctoral research was on adolescent spatial cognition, and his present research interests lie in maker movements and the affordances for learning of fictive worlds and virtual environments. Most recently, Kenneth is editing a book entitled "Maker Culture and Makerspaces: Landscapes of participatory making, modding and hacking".

Learning Spaces for Incubating Innovations: Cases in Singapore Secondary Schools

By *Wu Longkai*

THE IMMEDIATE ENGAGEMENT that is conceived from the interaction between the learner and the learning environment is a significant factor in a student's motivation to learn. The nature of learning arises from the reciprocity between students and their environment, especially if supported within authentic contexts. In meaningful forms of learning engagement, students experience heightened levels of concentration and sustained motivation especially in the continuation of tasks outside of school.

This talk describes observations from a study that was conducted in various learning spaces, detailing and investigating the experiences of the students while they interacted within these learning spaces. The study also investigates how a learning space can help to promote innovativeness in student learning and as a form of engagement for students to create, build and invent. These observations were made in three Secondary schools in Singapore.

Hence, we elaborate on three types of learning spaces (Figure 1) that are typically found in secondary schools within Singapore, supported by case studies.

Type I Learning Space in a Singapore School

Learning Space Example A—Nature High School

The following observations were collected during the students' Design and Technology (D&T) classes. The students attending these lessons are around 13–14 years old and have just transitioned from primary to secondary school. As part of their D&T curriculum, all students have to build a car using a standard kit pack provided for by the school at the end of the school term. The school organises a race at the end of the term for the students to compete in with their cars.

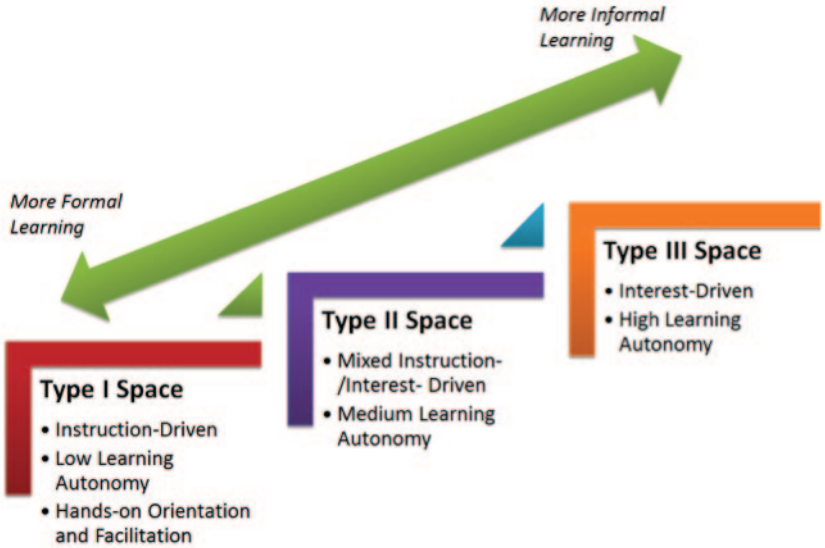

Figure 1. Three Types of Learning Spaces Incubating Innovations in Secondary Schools

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The lessons are highly structured—objectives of the lessons are stated at the start of the year, and the structured sequence of the lessons for the semester maintains a sense of purpose. The delivery of the lessons is highly instructive. Detailed step-by-step instructions are given, and all students have to follow closely the hands-on task-orientation and facilitation by the teacher. Although they are allowed room for creativity in terms of the artifact's design, all students have to produce the same artifact at the end of the term due to the standardisation of tasks. The students have no freedom to experiment on their own as all goals and methods of doing things are fixed. There is hardly any room for autonomy or improvisation because of the standardisation.

Type II Learning Space in a Singapore School

Learning Space Example B—Spring High School

The following observations were collected during the students' Science, Technology, Engineering and Mathematics (STEM) classes. The students attending these lessons are around 13–14 years old, and there is a teacher and a STEM facilitator present at every lesson. These STEM lessons have just been introduced in the Singapore curriculum, and are meant to encourage the acquisition of STEM knowledge and skills to solve real-world problems. The Ministry of Education in Singapore is also looking for opportunities to link schools up with industry partners, as these partnerships will serve to involve the industry by providing mentors or role models for students and to create awareness of STEM skills needed for the 21st century workforce.

Delivery of lessons is still quite instructive, but a more autonomy-supportive style is adopted. The facilitators and teachers allow time for self-paced learning to occur and when students encounter doubts, the facilitators and teachers do not provide answers immediately. Instead, they try to ask questions to elicit thinking in the students.

Students are still required to complete a number of tasks, but they are given some options in the tasks they can do and are given the liberty to look for resources online. Lessons are still pretty structured and students have limited freedom to experiment as most goals and methods of doing things are fixed.

Type III Learning Space in a Singapore School

Learning Space Example C—Summer High School

This learning environment is largely informal and the students who are present in this space are aged 12–17 years old. Peer-to-peer teaching and learning is encouraged and widely prevalent. Some goals are set (i.e., competitions) but students are fairly free to suggest what they intend to learn and innovate.

In an interview, two students involved suggest that their motivation to learn and innovate is not from formal lessons, but rather from their own life experiences and interests. They are fairly free to choose what they need to learn, as well as tinkering and experimenting with their own ideas.

Learning Spaces for Incubating Innovations: Cases in Singapore Secondary Schools

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[Student A]: Last time, my neighbor introduced me to the raspberry pi. It uses a programming language like python, basically a full-fledged computer that is credit card sized. So I just learned python online, through an online course.

[Student B]: … And I didn't take the course (in that subject area), because there is no such course online. I look at articles, find out and look at examples,other people that wrote the programs, just look at how they did it.

Overall, this space presents the most autonomy to the students. However, as this space is not typically part of the formal school curriculum, insufficient school support has been given to the students who demonstrated high degrees of interest and innovation.

About the Speaker

Wu Longkai is a Research Scientist in the Office of Education Research at the National Institute of Education, Singapore. His research interests include scaling and diffusion of innovations, ICT in Education, and informal learning studies.

School Library Learning Commons

Innovation and Educational Spaces: How Design Can Revitalize Our School Libraries and Learning

By *Loh Chin Ee*

IN DECEMBER 2015, Singapore was designated a UNESCO Creative City of Design, and the newly launched Design 2025 Masterplan aims to make design part of everyday living and working. Even as we grapple with how to make our education system more effective, less stressful and more equitable, I would like to suggest that design thinking can help educators come up with better solutions to pressing educational issues at both ground and national levels.

Design and Educational Space

Design is defined by the Design Council UK as:

…an activity that translates an idea into a blueprint for something useful, whether it's a car, a building, a graphic, a service or a process. The important part is the translation of the idea, though design's ability to spark the idea in the first place shouldn't be overlooked. (Design Council, n.d.)

In essence, design can be broadly viewed as engaging in activities to transform ideas into a plan for improving the quality of life or in this case, education. Design takes into account the needs of its users and should improve the lives of its users in doing so.

Within Singapore, there has been little discussion about how design can influence educational space and learning. Yet, the design and organization of educational space convey the dominant ideologies that shape the use of space, and can either enable or constrain the use of space for effective and transformative learning. Ian Grosvenor & Catherine Burke (2008) point out in their historical analysis of school buildings in the Western world that rather than viewing the school building as a "neutral or passive 'container'", we should understand it to be an "active agent, shaping the experience of school and promoting and even pioneering a particular understanding of education".

Such factors as the design of school furniture can be seen to reflect pervasive notions of pedagogy, but also to promote ideas and theories about the relationship between pupil and teacher and between body and mind in learning.

Thus, the essential question that educators need to engage with is: *How can we redesign educational space to encourage the kinds of 21st century learning dispositions (of criticality and creativity, of innovation and global-mindedness) desired?*

Educational Design

In thinking about educational design, it is important to consider three aspects of good educational design. Firstly, good design must be *functional*. Secondly, good design must be *equitable*. Thirdly, good design *requires mindset changes*.

School Library Learning Commons

Innovation and Educational Spaces: How Design Can Revitalize Our School Libraries and Learning

By *Loh Chin Ee*

Good Design must be Functional

Educational design should not be for the sole purposes of aesthetic pleasure but must take into account the needs of the students and the kinds of learning envisioned. For example, traditional classrooms with the teacher facing rows of students were the norm in the 1980s because the pedagogy tended to be teacher-centric (Liew, 1981). However, despite Singapore's forward-looking student-centered curriculum and pedagogies, the majority of classroom spaces may not have caught up with the pedagogical intent.

In my review of the research on the role of contemporary school libraries, it became clear to me that 21st century school libraries could be more central to student learning, whether in the area of reading (Adkins & Brendler, 2015), information literacy (Kapitzke & Bruce, 2006) or research (DelGuidice, 2015). The school library can serve as a place for reading, for research, for collaboration, for study and for doing (for example, in the form of Makerspaces [Loertscher, Preddy, & Derry, 2013]). However, most school libraries in Singapore remain under-utilised for such kinds of learning. How can the school library as an educational space be made more functional and effective for the kinds of 21st century learning desired? How can the school library be revitalised through attending to how function is met by form?

Good Design must be Equitable

Secondly, good educational design must be equitable. Educational equity requires a just distribution of resources at institutional, organisational, political and economic levels to ensure that the least advantaged have equal access to educational resources (Harvey, 2009). Although physical resources can technically be accessed by all, an individual's relative access may differ based on his or her access to transportation, entry fees, and the presence of adults who are able to ensure meaningful use of time in the educational space of the library (Jocson & Thorne-Wallington, 2013; Neuman & Celano, 2001). As such, the question of both physical and relative access must be a key factor in thinking about educational design: Who accesses these educational spaces? How are they accessed? What kinds of barriers to access exist? How can these resources be made available to a wider range of students, and for what purposes?

> Educational design should not be for the sole purposes of aesthetic pleasure but must take into account the needs of the students and the kinds of learning envisioned.
>
> – Loh Chin Ee,
> *English Language amd Literature Academic Group*

Good Design Requires Mindset Changes

The open-classroom concept popular in the United States and United Kingdom in the 1970s was a

failed project as many teachers who used the space could not adapt to the open spaces between classes. Moreover, the architects who had designed these educational spaces had not provisioned for the increased noise level that led to student distraction from learning. Good educational design thus needs to take into account teachers' capacity to cope with the change (Leander & Taylor, 2010), and to engage in sustainable innovation at the level of practical use.

> As the nation moves forward to encourage students to innovate, it is essential that we consider how our educational spaces can be creatively re-thought and re-designed to encourage innovation in and out of the classroom.
>
> – Loh Chin Ee

Rather than condemning the idea of an open-concept classroom or teachers for being inflexible and unwilling to change, this example illustrates that educational design is a form of multi-disciplinary work requiring the co-operation of the architect, designer, school management and teachers to come to a clear idea for the kinds of learning desired. From the dialogue, the stakeholders can subsequently design a blueprint that will effectively encourage the kinds of 21st century learning desired for the localised needs of each particular school. As educational spaces are redesigned, pedagogical readiness must be ensured for successful use of these redesigned spaces.

As the nation moves forward to encourage students to innovate, it is essential that we consider how our educational spaces can be creatively re-thought and re-designed to encourage innovation in and out of the classroom. While school libraries are one space that can be revitalised through design thinking, there are certainly other educational spaces that can be reworked to ensure innovative and equitable education for all.

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About the Speaker

Loh Chin Ee is Assistant Professor in the English Language and Literature Academic Group at the National Institute of Education, Singapore. Her research interests include curriculum, instructional and assessment practices in literature education, literacy/literature and globalization, and pre-service and teacher education. Her current research focus is on reading and school libraries.

Panel Discussion

Panel Chair *Dennis Kwek*

DENNIS KWEK

Dr Wu Longkai talked about driving interest being quite an important part of innovation. So for all the speakers, what drove you to do the research that led to your presentations?

Wu Longkai

Firstly, that is of course my interest. Secondly, I think there is a lot of talk about formal and informal learning because we—me and my NIE colleagues—have done a lot of research on formal and informal learning. It is still quite an unexplored space. I think when we talk about informal learning, having an interest really plays a part. In my research, I think this is something NIE researchers and their research can help the teachers and schools with.

Kenneth Y. T. Lim

Thank you, Dr Wu. In my case, I think my interest in maker culture started around 2011 or 2012. I think there is an increasing recognition that the positions around making and hacking aligned with some of the people-centric dispositions that our education system wants to nurture. I think a lot of the dispositions are already happening in schools; it is just that we need to learn to recognize them even though they may be at unlikely places.

Michael Tan

I guess for me, my personal interest in this is irrelevant. We find ourselves at a time where we realize we need to do certain things to perpetuate our level of success. It requires us to re-imagine what society ought to be like. If we do that, one of the questions that come forward is: *How do we do it?* In my perspective, the best way to answer that is from a design perspective and with trans-disciplinary lenses.

...there is an increasing recognition that the positions around making and hacking aligned with some of the people-centric dispositions that our education system wants to nurture.

– Kenneth Y. T. Lim,
Office of Education Research

Loh Chin Ee

Do you ever feel that life kind of starts and then you make a full circle before you return to the start? I always loved hanging out at the library and now my work is on libraries. Essentially, I am focussing on this because I feel this is an area where I can make visible changes on. If I work with the Ministry of Education (MOE) and the National Library Board, and do something to change library spaces, it can benefit students from low-income backgrounds. Ultimately, I think education needs to be equitable.

DENNIS KWEK

Thank you, everyone. Talking about life and full circles, for those of you who might be around

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my age or were born in the early-80s, you might remember metal and woodworking in Design & Technology (D&T) where we had to construct or make something. What I always remember about that is a wooden door stop. I had no choice; I had to make a door stop with very specific dimensions or I will fail the course.

But yet, when we talk about *making* and *innovating* here, the keywords that are popping up include autonomy, interest, designing spaces, transgression, inter-disciplinarity, celebrating failures, imagination. But those words are almost alien in our current educational context. Do you agree? Like what Kenneth mentioned earlier, good things that occur in schools perhaps occur in the informal context but not in the formal context.

Michael Tan

I have a project that looks at 10 schools and 2 of them describe "hack" as part of a D&T curriculum and pedagogy. And by "hack", I don't mean nefarious activity. "Hack" here is referred to in its original term: For example, when a computer scientist uses computers to create things that weren't initially intended, such as playing music on mobile phones. This is why your iPhone can play music now, by the way. Anyway, so we were there hacking at the D&T curriculum and pedagogy. One of the things that they were doing initially when we first came on board is still being done now, but a lot of it has changed. There is a strong design element involved now but it can still be further strengthened.

AUDIENCE MEMBER 1

I am from Curriculum Planning and Development Division and I oversee D&T education at MOE headquarters. The woodwork described earlier on is no longer in existence today because Singapore has moved on. What we have today is D&T as described by Dr Tan.

When Dr Wu was talking about informal learning space, I was just thinking: *Is it not possible for informal learning space to exist in formal curriculum?* And the answer is yes, it can occur in the D&T classrooms. In the D&T classrooms, students could still do well in a national examination even though they came up with a solution that did not work at all. It is still possible to get a distinction in D&T at O levels simply because a student went through a deep design thinking process even though the end product was not a success. So in today's context, this kind of informal learning, highly driven by students' interest, does exist in formal school curriculum.

> ...you need teachers who can model the risk-taking disposition.
>
> – Michael Tan
> *Office of Education Research*

Michael Tan

One of the things that has happened before is that when I spoke to a group of LEP (Leaders in Education

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Programme) trainees, one of the questions that was asked was similar to yours. How do we find teachers like this to make the makerspaces? At that point in time, we didn't really have a teacher education program with components that has this kind of disposition. I remember thinking at that point of time that this is very hard because you need teachers who can model the risk-taking disposition.

So I think what needs to be done is that from the primary school level, we need to stop insisting that we have "a vision for tomorrow". When do we give opportunities for students to come up with their own best initiatives and ideas? While we have a solution—D&T—I think it needs to be more than that. It cannot just be in that one subject, which is only 1.5 hours a week, that students are allowed to become creative whereas the rest of the time, they listen to us because we have "a vision for tomorrow".

AUDIENCE MEMBER 2

With regards to hacking in the D&T classrooms, I would like to hear examples on how students are assessed. I am currently looking at some research data from Vietnam and some of these Vietnamese schools are moving away from traditional assessment.

Michael Tan

For the assessment part, I think most of what we have seen so far for D&T is on a portfolio basis. But we have been advocating for a different way of approaching assessment because the end product is not exactly necessarily going to be a good enough measure for success because the process in which students take to get to the final product—and the product could be a failure but yet had multiple iterations, and multiple prototypes that have demonstrated students' efforts in the process—needs to be rewarded.

> ...the process in which students take to get to the final product—and the product could be a failure but yet had multiple iterations, and multiple prototypes that have demonstrated students' efforts in the process—needs to be rewarded.
>
> – Michael Tan

AUDIENCE MEMBER 2

My second question is open to all—what is the hacking or tinkering happening at the teacher education level? Because definitely, teachers are part of the makerspace whether they are behind the scene or part of the group. We heard about the teacher-librarian in the library that Dr Loh talked about. How are teachers prepared from the teacher education perspective?

Loh Chin Ee

I would like to respond to the question about what the teachers are doing, although not so much at NIE.

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In my other research study that I did with Dr Warren Mark Liew on teacher education, specifically English teachers, one thing that we found was that the teachers spent a lot of time marking. This is especially so for the younger teachers. They are very stressed up because they are adjusting and spending a lot of time marking, and doing curriculum planning. My answer is that we need to give teachers time to hack. But this also might be a concern because while some teachers hack, the others might "slack" (that is, some teachers might be seen to be doing more work than others). But I do think we need to give teachers time and that sort of space for thinking. We have that space currently, but i think it is insufficient.

> ...we need to give teachers time to hack...and that sort of space for thinking.
>
> – Loh Chin Ee,
> *English Language amd Literature Academic Group*

AUDIENCE MEMBER 2

Lastly, where do industry experts or people from the workforce come in? This is because D&T is tied to future skills and future workforce. How are we bringing in these experts into this space?

Loh Chin Ee

With regards to my work on school libraries, one of the things i am advocating for is that, maybe we need teacher-librarians, which isn't a norm in the Singapore context. The teacher-librarian is someone who has a degree or diploma, someone who is trained to manage the library not just as a librarian but also as a teacher that is able to plan information literacy lessons.

For example, a history teacher wants to do a research on a particular historical topic. So the teacher-librarian will help that teacher find the materials required and prepare all that resources that his/her students can use to do research. That is the role of a teacher-librarian. So I was thinking on roles we can create for people who are teachers but not actually be in the classroom. Is there a possibility for that kind of manpower in our schools?

Kenneth Y. T. Lim

I brought the makerspace to the attention of the school leaders, and then to the school's middle management, specifically to the teachers in charge of the National Cadet Corps (NCC) (Air), they were actually quite horrified because to them, the children were doing things which were not core to the NCC (Air) curriculum. They actually did shut it down. It is very sad. It is also ironic that while the NCC (Air) commandant—who is the overall in-charge of

> I always talk about tension between the makerspace activities and academic rigour, and I think how we manage the tension and mediate opportunities is really the key to how we proceed forward.
>
> – Kenneth Y. T. Lim

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NCC air in Singapore—recognised what is going on, the power of learning and the trans-disciplinarity of makerspace, he was unable to help the school understand these benefits.

I always talk about tension between the makerspace activities and academic rigour, and i think how we manage the tension and mediate opportunities is really the key to how we proceed forward. So we actually do have "a vision for tomorrow", just that, it is a slightly more widened one.

Wu Longkai

To me, it is about the interest in the school. We have interviewed some students from secondary schools. They are extremely interested in coding and their schools have actually developed certain programs for coding. In that case, we can see that the students are really happy that they can collaborate with all this. They can have guidance from their teachers. That is the case when there is special interest. However, this kind of interest-driven learning, to me, is sometimes a privilege. But as a system, we are trying to engage most of the students. How can schools meet with all the interest of *all* students? I think that is a fundamental gap we are discussing.

> How can schools meet with all the interest of *all* students? I think that is a fundamental gap we are discussing.
>
> – Wu Longkai,
> *Office of Education Research*

AUDIENCE MEMBER 3

You mentioned about the makerspaces requiring a mindset shift or buy-ins from school. How would you address this? Most important is to get buy-in from teaching and learning perspectives, as a school leader, school committee member and teachers as well. How would you encourage that?

Michael Tan

I guess part of it is you need to convince them. The good old-fashioned way of doing so is to set up a committee and get these people involved. That, I suppose could work. But there is always the problem of quantity versus quality. They may look at what you want or the key performance indicator, and give you exactly just that. But i think there is a better way to do it. We can sort of nurture and allow for this innovation messiness and chaos to bubble up from below, rather than deliberately make it happen.

Take for example Carnegie Mellon University; They have this thing called The First Penguin award. What is that? If you notice penguins' behaviours in the South Pole, they will huddle around an iceberg because it is safe. However, then they can't eat because they need to go into the water to hunt. After some time, the first penguin will jump into the water, or get pushed off by somebody behind. So it goes into the water, struggles a little bit, and if it comes out alive, the rest will jump in too. But if it jumps in, doesn't resurface, then the rest will not jump in. So The First Penguin award recognises the individual who takes the risk to try something new that they

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are passionate about. Perhaps schools could do something similar like that. But I don't think it is a uniformly good thing that all schools need to jump onto this innovation bandwagon. If we want students to be passionate and innovative, I think teachers need to model that first. The school leader and culture should model this ability to recognize passion.

> We can sort of nurture and allow for this innovation messiness and chaos to bubble up from below, rather than to deliberately make it happen.
>
> – Michael Tan

Loh Chin Ee

I want to share about this idea of evidence-based research from library science. In countries such as the US where teacher-librarians are the norm, because of funding cuts, some schools try to do away with these unnecessary roles. So there are many advocates going on and one of the arms of the advocacy is the idea of evidence-based research, which any teachers can do. It essentially means that you need to determine what is the space being used for or what innovations are supposed to be for.

For example, say, I want to see libraries as a reading space or as a research space. So I determine that these two are the main components. Then I am going to have the measurable indicators to evaluate the use of that space. So in the library research, when we talk about "evidence-based", it is knowing very clearly what you want to measure, coming up with the criteria for what you are going to measure, and starting to measure it.

So I get teachers to do a survey, I talk to students and I gather feedback about what your library is like right now. And then when you have made that change to the library, I do a survey again or I talk to the students to try to figure out if you at least have achieved it. If there are successes, however minor, inform the principal and perhaps request for more funding for further work.

Kenneth Y. T. Lim

I would echo that. I think it would be a good way to start; celebrate successes and look for champions in your existing school culture. That is what I am trying to get at. Champions can be found in the most unlikely places. They may not always be the high-achieving students or your very motivated teachers. The other thing that I would like to say is perhaps, we can also start thinking about shifting conversations from making and fabrications to design. I really appreciate Dr Loh's presence here because she is giving us valuable perspectives that actually transcend our narrow educational goal. For example, in Geography, there is geographical investigation, which is a big thing a lot of us are grappling with. In terms of geographical investigations and inquiry, the thought processes that one goes through in crafting and investigation are very similar to that when designing an experiment.

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DENNIS KWEK

Any other questions? It appeared that one of the things that keeps appearing is the tension between formal and informal contexts. Is that the case, should we leave it as it is in terms of current learning environments that we have now, or should we be doing more, and if so, where should we be doing it? Leave it as it is? Students have co-curricular activities (CCA) after all. They have informal learning after school, which most of us don't document.

Wu Longkai

To me, informal and formal learning elements can coexist. Based on observations, both elements are coexisting in certain scenarios. There is still teacher instruction and student creation. There are student-centered kinds of individual exploration. So all the elements can coexist in schools. When we talk about formal and informal learning, it is really about crossing the boundaries of schooling. This is a new form of learning and we know that the system is trying to provide support in this kind of, we can call it, *learning anywhere, learning anytime*. The challenge is about what can we learn from informal learning and try to influence formal learning. I think that is what we are trying to do because in informal learning, we see more students' creativity and innovations. Student-centered learning is happening in informal learning. How can we use that in the formal learning?

> The challenge is about what can we learn from informal learning and try to influence formal learning.
>
> – Wu Longkai,

AUDIENCE MEMBER 4

It seems that informal space is more suited to interest-driven learning while formal space is more suited to non-interest-driven learning. So, would CCA be considered informal learning? And if CCA is graded and has an impact on high-stakes examination towards the next level of education, would graded CCA be informal or formal learning?

Michael Tan

I don't really like this formal/informal distinction because I think it sets up an artificial dichotomy that is almost to say, "formal" equals "boring", just hard work, and "informal" is "fun". I think there's a problem with that. We make it sound like the stuff in formal education, the stuff that gets you your grades is more important, while you do informal learning, well, informally, and just when you have time. The problem is that increasingly with grade inflation, highly competitive engineering schools like Massachusetts Institute of Technology are no longer accepting people with perfect scores if they don't have a good making portfolio. So if you've never touched a screwdriver, never made something, you won't get into MIT .

Ken Robinson said that if you think about it, the system of public education around the world is a protracted process of university entrance. And the

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consequence is that many highly talented, brilliant, creative people think they are not, because the thing they were good at wasn't valued at school and was actually stigmatised. I don't think we can afford to go on that way.

In focusing on school rankings and KPIs, we miss out a lot of other ways in which people can be creative and innovative. We are no longer talking in terms of "how creative are you", but rather "how are you creative". That kind of mindset shift needs to be more widely recognised.

Kenneth Y. T. Lim

This thing about creativity is very fuzzy. If you asked a room of 28 people you'll probably get 42 different answers of how to define creativity. I think domain knowledge—deep disciplinary knowledge—and creativity go hand in hand. As in Dr Wu's three-step ladder—he wasn't trying to speak pejoratively about the lower parts of the ladder, but he was trying to make the point that in order to get to the higher parts, you need to slog through the lower parts. Likewise I think we do need the deep disciplinary knowledge that comes from formal curriculum in order for us to thereafter have the creative spark. But Dr Loh's excellent point is also that we also need the time and space to be created for this. Because we can have very brilliant and creative people, but not so academically brilliant, and if they're not allowed the time to reflect, to fail, they will never be creative.

Michael Tan

It's probably an academic disagreement, but it's not true you have to be schooled in disciplinary knowledge first before you have time to be creative. Part of the traditional way of conceptualizing higher-order thinking is this harmful notion that you have to work on basics before you become creative. However, it's not "one or the other" or a linear progression. And it also doesn't necessarily mean that pedagogically speaking, you cannot approach learning from an interest-driven perspective by giving students a project that drives their interest—a concrete experience first—and encourages them to look deeply into the methods to discover the formalisms.

Let's take Newton's laws of motions as an example. The traditional way of teaching the laws in physics instruction is telling you that Newton's laws states this, then memorise the equations, then we do a lab where you figure out what it means. That isn't the best way of doing that. In fact, a lot of times, grounded experience is very important for a deeper appreciation of formalisms.

Loh Chin Ee

I think both of you were talking about practice. In order to do that "something", you need to practice at "something". I like to think of the issue of a school being able to evaluate itself in terms of the larger question "If our school is a school that encourages creativity, what evidence is there of creativity in the formal curriculum and in the informal curriculum?"

An example of Type 1 (in Dr Wu's typology of learning spaces): In my son's P1 classes, they have a programme where teachers come in and do creative games with the students, such as story cubes. That's a programme going on for the general crowd to

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encourage them to be creative. But there's also Odyssey of the Mind for those who are interested, want to take it further and are willing to spend the extra time. So it's about evaluating the school culture and taking a broad look at the dispositions that we want to encourage, and seeing what kinds of practices are going on at various levels to encourage these things.

> "If our school is a school that encourages creativity, what evidence is there of creativity in the formal curriculum and in the informal curriculum?"
>
> – Loh Chin Ee

AUDIENCE MEMBER 5

I wanted to add a comment to Dr Lim's point. I agree with part of his point that expertise or depth in a domain adds a lot of value, and fundamentals have a role to play. And I also agree it doesn't have to be linear, but I think fundamentals go further. It's a continuum we're talking about. Not to mention the point about entrepreneurs over 50. The fashion used to be you're a college dropout and you build something, which doesn't have to be the case anymore. The 50-something entrepreneurs have years of experience in their field, leadership and other qualities, then become innovative. Which means that they have built some depth. So it doesn't hurt to gain domain knowledge and fundamentals, which are a part of getting creative because you know the fundamentals well, which you can develop later. It's a grey area, not one or the other, but domain knowledge does help.

DENNIS KWEK

Thank you. So we have heard from the speakers today about innovation, education, and educating for innovation; how a number of dispositions are important for innovation as well as the nature of interdisciplinarity; the nature of task design; resources and support needed for schools; the kinds of tensions that happen whether it's informal or formal learning; and the importance of space and design of spaces, which are issues that education researchers tend not to think too much about. We've also heard about the importance of social environment; having a diversity of interests in schools is increasingly important as well. And celebrating failure—The First Penguin. Too often, people are penalised for failure. Now I think there's a need, especially if you want to become a little bit more innovative, to be a little bit more open to failure and to risks.

So I want to thank everybody for coming today. We'll have a number of other seminars and discussions about innovations as we proceed along, so please keep an eye out for these.

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