Chapter 2
Nurturing Maker Dispositions Among Children with Open-Source Tools: A Case Study of a Junior High School in Singapore

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Abstract The recent phenomenon of maker culture has garnered the interest of educators as arguments have been advanced for the foregrounding of making in learning. Making in learning is an example of how participatory cultures of learning focus on authentic contexts outside of the formal spatial and temporal bounds of schooling. This chapter describes how a specialized school in Singapore made use of a curriculum design framework known as the Six Learnings (Lim,.Journal of Virtual Worlds Research 2:4–11, 2009) because of its origins in contexts of learning such as games and immersive environments. The authors facilitated the process and based the design and principles of the learning space to articulate key dispositions in learners through the nurturing of a culture of making. Foundational to the activity was a commitment to reconceptualizing the emphasis on routine tasks and instructions that are typically present in a formal classroom setting.

2.1 Introduction

Since the industrial revolution, the development of civil societies in the West has been characterized by periods of steady growth and relative stability. Progress was understood from a Kuhnian (1962) perspective of paradigms, perturbations and consensus building; this resulted in long periods of steady state, each of which lasting for several decades. In turn, these steady states meant that skills could be developed over time, knowledge bases could be incrementally grown, and both knowledge and skill sets remained relevant throughout a person's lifetime; career paths were clear,

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and systems of education designed along functional philosophies were able to service the needs of countries well.

From the latter half of the twentieth century—precipitated by the forces of globalization and the imperatives of networked social and economic architectures—the assumptions of steady state that had so successfully undergirded statecraft in Singapore and the West rapidly lost their validity. Instead, we characterize societies in the twenty-first century as being in a continual and dynamic state of change, driven—for example—by exponential advances in computation. These advances hold far-reaching implications for social practices and genres of socio-economic participation that we are continually articulating. The implications include those pertaining to how children learn, the nature of disciplinary understanding and the social co-negotiation of structures of authority and trust.

As such societies are much less hierarchical compared to the past, and consistent with Anderson's (2006) notions of the long tail, children from all social and economic strata can have opportunities to move up the social ladder. Schooling systems have historically been designed largely based on an industrial model and mass production of skills; in such systems, the impartation of knowledge through rote and memorization were dominant. However, the highly structured nature of schooling today can be complemented by more emergent and unstructured forms of informal learning, including networks of practice existing in social media and online worlds.

Singapore's education system has largely been very successful with a very strong academic emphasis. Science, math and engineering have been the dominant staples of economic success. The system began with the streaming of students, but has now evolved such that students on different tracks can move from one track to another.

However, members of Singapore's senior political leadership have recently alluded that the education system may have also stratified the student population, and while we acknowledge that not all students can attain the same degree of academic performance, care should be taken to cultivate students' abilities to the fullest.

Instead of obliging everyone to conform to the same mould of academic performance, this chapter attempts to frame a context—or a remaking of a context—in Singapore in which multiple talents and disciplines are widely recognized as advantageous; this is especially critical to sustain economic development in Singapore in a world increasingly characterized by instability and unpredictability.

In the twenty-first century when imagination and play are critical, the talents of all our students, especially the academically lower achieving students, should be harnessed. These latter cohorts of children have always been stronger at expressing themselves through non-traditionally academic means, such as through the visual and performing arts, and through craft and design thinking. With regard to the latter especially, there is an increasing recognition—since Brown's (2008) seminal paper in the Harvard Business Review—that these are dispositions and expertise sets are of critical value to ensuring the nimbleness and adaptivity of societies in the twenty-first century. This is in large part because disciplinary domains are less accurately described as 'stocks' of knowledge, but as 'flows' in an age of the networked learner. In such a characterization, learners are adopting much more co-equal stances with

more traditional domain arbiters as they participate and negotiate in the de- and reconstruction of knowledge and the ontologies thereof. To quote Weinberger (2012):

> we used to know how to know. We got our answers from books or experts. We'd nail down the facts and move on. We even had canons. But in the internet age, knowledge has moved onto networks. There's more knowledge than ever, but it's different. Topics have no boundaries, and nobody agrees on anything.

It is worthwhile to note that the point that Weinberger is making is not one of information overload—that would be too superficial a reading of his critique. Instead, Weinberger is highlighting the malleability of modern manifestations of knowledge, and how this malleability has resulted in the arbitrations of knowledge as being more contested than it has ever been in human history.

It is our view that—from such a framing, at least—good questions are more important than good answers. We can learn from the maker movement as to how a respect for a diversity talents can be nurtured.

2.2 Maker Culture

The recent phenomena of maker movements in Germany and the USA are very good examples of the increasingly participatory culture of learning that characterizes so much learning in authentic contexts outside of the formal spatial and temporal bounds of schooling. Turning Descartes's *cogito ergo sum* on to its postmodern head, maker movements recognize that understanding is socially constructed and frame it in terms of *participate ergo es*—we participate therefore we are; the very act of legitimate peripheral participation in socially authentic contexts engages selves in dialectic coupling with the social corpus in ongoing shapings and negotiations on identity.

2.2.1 Homo Faber

The learnings that accrue from defining ourselves as social beings—in relation to social others—are very different from those which arise from an understanding of self as a stand-alone construct; the latter reinforces a notion of the acquisition of knowledge as stock, the former foregrounds an understanding of the negotiation of knowledge as flow.

To elaborate, learners are engaging in participatory performances in which they derive authenticity thrive on—and look forward to—having their respective creative processes critiqued by social others; one only needs to look at trust-based online communities—such as Flickr, YouTube, eBay, Amazon and fan-authored wikis—for evidence of this. This can be thought of as akin to a shift from a quasi-Cartesian 'I am what I own/I am what I control' to 'I am what I share with others to build upon'.

In such settings, learners 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. In such performative environments, the traditionally binary distinctions between success and failure are rendered meaningless, because the learners realize for themselves they are not only seeking a continuously shifting bar, but—critically—that they have some influence over the nature of the bar itself. That is to say, the learners realize for themselves they have the ability to create their own contexts for personally meaningful experiences of learning.

2.2.2 Homo Ludens

Learners engage in the creation and curation of contexts, through deliberate participation in play. By 'play', we refer not only to situations in which the learners are actively participating in the structured activities of games, but also to the dispositional approach of the learner to attempting to understand whatever is presently holding his/her attention as a system to be analysed, de- and reconstructed (either/or both metaphorically and/or literally). Play is therefore an extremely intentional activity, and it is also a disposition which is increasingly defined in negotiation with one's social others.

Framing learning through the disposition of play is important, because it has the corollary that 'failure' (as traditionally defined) is an option—to the extent that it is understood as a learning opportunity—the whole concept of 'cheating' (taking a shortcut to success) is also rendered invalid because the learners would not stand to gain personally from having 'cheated'. Cheating is only a worthwhile strategy if assessment is understood as a stand-alone output ('stock'), as in 'I won'/'I achieved the highest score'; it loses its validity once personal worth is understood as a developmental process ('flow'), as in 'I am getting better at this'/'I am understanding better how this works'. Further, few think of leveraging the technologies to 'cheat', because they realize for themselves the hit that would mean to their reputations in these communities—the premium that Shakespeare's Othello placed on reputation still rings true today. In this way, these interest-driven communities have helped redefine understandings of apprenticeship, in ways which extend its roots from social enculturation into a more contemporary understanding of the nature of the learner and the learned.

2.3 The Maker Movement in Education

The maker movement has been making waves in education lately as progressive educators have argued for a more active role of making in learning. Perhaps one of the earliest known ideas of learning from making was from a Swiss education reformer. Pestalozzi (1746–1827) believed that learning should be a cross-curricular balance between the 'head, hand and heart'. He gave great consideration to what children could learn from nature, play and from observations of the world. Pestalozzi believed that learning resulted from the learner's own self-activity and first-hand experiences. He recognized that the interests and needs of the child should be nurtured, in a child-centred rather than teacher-centred approach to teaching.

Like Pestalozzi (1912), psychologist Jean Piaget, more than a century later, formalized these ideas with his theories of constructivism. In his *To understand is to invent*, he advocated that 'every new truth to be learned, be rediscovered, or at least reconstructed by the student and not simply imported to him' (Piaget, 1976, p. 15). He also called for teachers to teach from an 'interdisciplinary point of view' and to give 'general significance to the structures they use and to reintegrate them into overall systems embracing the other disciplines' (Piaget, 1976, p. 29).

Similarly, Seymour Papert, who is known for his theory of constructionism, positions the embodied, production-based experiences as the basis of how people learn (Harel & Papert, 1991). Papert, whose theory of learning undergirds the maker movement's emphasis on problem-solving and digital and physical fabrication, has been ascribed as the 'the father of the maker movement' (Martinez & Stager, 2013, p. 17). Papert (1993) postulated that it was the physical process of constructing an object that would help students develop and demonstrate an understanding of the subject they were learning. That meant that students would be able to learn effectively by actively constructing knowledge through the act of making (Martinez & Stager, 2013).

Today, the presence of technology offers learners tremendous resources and plays a significant role in the maker movement. Technological experimentation and the availability of digital devices and technologies like open-source 3D design programmes are just some of the tools that support a learner's design and construction goals.

State Craft and Street Craft

To date, the Singapore government has been effective in creating new contexts for learning through careful planning. An example is the so-called specialized schools, which were set up in order to cultivate talent in the arts, sports and math/science, the Ministry of Education in collaboration with other ministries created specialized schools to cultivate and nurture such talent. The 'context' created enables new forms of interactions to occur. These new forms include exploiting on professional practices and practitioners to advance skills and dispositional cultivations. Academic teachers have closer relationships with practitioners within the same community networks.

While we acknowledge that the state engineered and planned for these schools, enabling new contexts to be engendered, students in these schools were also able

to delve into creating new possibilities in learning. In other words, the government enabled an environment (what might be termed big 'C'—context) where small 'c's were able to be created by the students, teachers and practitioners from these respective specialized schools.

We acknowledge that these specialized schools are expensive relative to typical schools, but they clearly serve a different purpose. In the overall ecology of schools, we need to have a diversity where talents can be harnessed, but importantly, cross-fertilizations need to be encouraged.

The maker movements in the USA exhibit a deep web of social relationships and networks where individuals come together to make things. In a sense, these maker movements are very similar to open-source communities which acted as a counter-force to the institutional giants. One wonders if there were no big giants whether these counter-forces would have flourished. In the overall ecology, we believe we need both kinds of forces.

In a way, the manifestation of government is akin to the 'institutional giants'. In Singapore, we should encourage these counter-movements rather than seeking to quench them. The issue should be defined in terms of how to manage these tensions productively.

2.3.1 'Minds on' and 'Hands on'

The maker movements show the intertwining nature of 'hands on' and 'minds on'. In the quest for achieving their goals, these individuals exhibit passion and tap upon these networks to solve authentic problems. They both make and think in a close knit manner, tacitly knowing (Thomas & Brown, 2011) how to source the requisite resources in a just-in-time manner. In this sense, mind and body are not divorced, just as plans are not divorced from actions.

The industrial revolution privileged the Cartesian model where abstracted knowledge is legitimized, and students learned and are assessed predominately through a minds-on pedagogy. Minds on, the derivation of good plans through critical thinking, epitomizes the Cartesian worldview. This assumes the stability of the world around. However, going ahead, it behoves us to seriously reconsider this worldview and to return to the inextricable relationship between cognition and context. Hence, the dialectical nature of a minds-on–hands-on philosophy. Situated in the appropriate nurturing contexts, a 'hearts-on' disposition would also be fostered since the leverages of embodiment in social practices are designed for.

2.3.2 Planning and Playing

Not only have we to acknowledge the inextricable nature of cognition and context, Thomas and Brown (2011) also posit that today's tools and environments afford

learners to create new contexts. The creation of contexts is not only the privilege of the established institutions, but big 'C' can be possible even for those traditionally seen as outliers and at the periphery of society (e.g. children). Such a disposition should be encouraged as it requires both play and imagination to create new possibilities and worlds. Children all over the world are creating small 'c' through the creation of powerful, compelling and complex narratives (fan-fiction) upon these imagined worlds.

If we look beyond the academic performance of specialized schools in Singapore, there are common interests and dispositions which can be leveraged upon. The collective coming together of these students can enable and catalyse an 'edge' phenomena, and because these students come from academic scores that can be wide, a cross-fertilization of students' play and imagination can be recognized to permeate across social strata.

2.4 Background to the Case Study

Quest High (QH) is one such specialized school in Singapore. It provides a customized, technical-based curriculum that is designed for hands-on and practical learning. There is less emphasis on academic-focused methods, and the learning environment goes beyond the traditional academic demands of a regular classroom. The school's broader objective is also to provide multiple pathways that cater for the different learning needs of students.

In 2013, researchers from the National Institute of Education in Singapore worked with three teachers and fourteen students of Quest's New Media Club, to design and build a full-scale model and simulation of the school campus using an open-source platform, OpenSim. It was a two-year project with the students (13–15 years old), who built a 3D virtual model of the campus as their vision of how the actual school campus might evolve in five years' time. The final artefact, a video of the virtual campus, was showcased during the school's opening ceremony.

The researchers facilitated the process and based the design and principles of the learning space to articulate the key features of the maker culture. Underlying all of this was a commitment to reconceptualizing the emphasis on routine tasks and instructions that was typically present in a formal classroom setting. However, as the students and teachers were new to a non-traditional learning environment, the facilitators played a crucial role in trying to balance the ethos behind the maker culture and the expectations of the school.

The school was designed to unlock the hidden talents of low process learners, to help develop their potential in a persistent and sustained way, by consistently building on their successes over time. There is also a long-term objective of developing the holistic growth of the students. To address their social–emotional needs, there are personal and social learning, physical and aesthetics programmes that cater to helping students acquire the values and competencies needed to succeed in post-secondary education and eventually in employment and in life.

For more realistic learning situations, the school collaborates closely with industry partners to develop programmes and attachment opportunities, which are in industries that students can work in after graduation. The pedagogy adopted in the school emphasizes skills-based activities and practical learning in a real-world context or workplace setting. In order to facilitate its skills-based pedagogy and programmes, QH adopts a higher teacher-to-student ratio, with a class size of twenty students. This is in contrast to classroom sizes in Singapore, with typically forty students in each class.

Apart from their core subjects, students are exposed to vocational skills in four areas—facility services, mechanical servicing, retail services or hospitality services. The purpose of having these vocational modules serves to illustrate the relevance of academics to students and to help them pick up skills-based, practice-oriented training and as a basic foundation of technical skills applicable to their daily lives.

The school has garnered the support of partners and the community to design the classrooms after an actual supermarket and a local Do-It-Yourself 'DIY' retail chain, thus providing students with a more realistic learning environment. For instance, students will see how learning about percentages during math class is relevant to calculating discounts when attending to customers in a retail job.

2.5 Design of the Study

School leaders have witnessed the progress that students have made after being exposed to authentic learning environments and have highlighted how it is beneficial for students to see the relevance of what they are learning. They have noted that when there is a link to a situation that students are familiar with, learning becomes authentic and engagement levels will increase.

Making develops an alternative way of learning, one that contrasts with mere abstract analysis. It provides learners the opportunity with work with both the 'hand' and the 'head'. By engaging both the head and the mind is a way to engage students who have difficulty applying what they know to the world around them. These are the principles that undergird the intervention in Quest High, which will be described further in the subsequent sections.

The first stage of the project consisted of mapping and identifying the additions and development potentials the students could imagine in their school in five years. Following that the students devised a survey instrument and administered it using an online tool, to their peers from the rest of the school. They then used the results from the survey to shortlist a number of new improvements which they would like to see in the school. Thereafter, the students brainstormed and developed a range of ideas and suggestions for solutions to the identified problems that were raised and executed them in OpenSim. The whole context of the learning experience was centred on an ethos of 'making and doing', instead of a 'sit back and be told' school culture, in which students exercised self-efficacy by solving set challenges in a student-led environment (Claxton, 2008; Gaunlett, 2013).

In the study, it was designed for the students to exercise their own autonomy and not be dependent on the facilitators for help. However, the researchers understood that as the students and teachers were new to this pedagogical approach and that the students might not be able to adapt to it at the start, the initial two sessions would be slightly structured. The students were taught basic building concepts and specific operations, like how to create a design primitive ('prim'), how to clone it and how to apply mathematical translations to it. Then as the students got used to this approach, the facilitators would get them to start exploring on their own. The students were encouraged to start building what they wanted and the facilitator would be available to help and support them as needed. Some students needed more encouragement than others, but most students were eager to try out and start exploring on their own.

2.5.1 The Six Learnings Curriculum Design Framework

In most school activities, structure is valued over unplanned, free-structured learning. Creating a spontaneous learning environment that breaks a carefully planned structure is difficult as it requires a new teacher mindset that entails giving the students the autonomy to do things differently. When learners are allowed to experiment, to take risks and play with their own ideas, we give them the freedom to explore their own interests. They start to see themselves as capable of having good ideas and the ability to turn their ideas to reality.

The Singapore education system has evolved from a highly prescriptive to one that allows for an increasing degree of school autonomy in terms of resource management and pedagogical experimentations (Ng, 2010, 2013). Although these mitigating approaches have been introduced to promote a more holistic and student-centred curriculum, these reforms are still in their nascent stages, and generally, schools are still very much accountable to the pragmatics and economic considerations of the Ministry of Education (Lee et al., 2016).

At Quest, we had to think about how to support a student-centred learning environment while balancing it with meeting the deadline of completing the virtual campus. The curriculum design framework we adopted was the Six Learnings framework for the design of learning environments, which is particularly well suited to contexts of learning within games and immersive environments (Lim, 2009). Briefly, the Six Learnings are: Learning by Exploring, Learning by Collaborating, Learning by Being, Learning by Building, Learning by Championing, and Learning by Expressing. Together, they describe the six primary affordances for learning, of game-based worlds and immersive environments. For the purposes of the study reported in this chapter, the Learnings of particular relevance are Learning by Collaborating and Learning by Building. To quote Lim (2009):

> By 'Learning by collaborating' is meant the learning that results when students work in teams, either on problem-solving tasks or in other forms of structured inquiry. The focus here would be on helping the learners increase their metacognitive habits as well as their understanding of distributed cognition and the social dynamics of group work in general.

This learning draws on the rich body of established literature on the benefits of learning collaboratively, as opposed to learning competitively (e.g., Johnson & Johnson, 1994).

By 'Learning by building' is meant the learning that results from tasks that require the learners to build objects and / or script them. Such activities could potentially involve the demonstration of mathematical understandings of trigonometry and physics, the learners' sense of aesthetics, as well as their grasp of the logical algorithmic flows inherent in a scripting language. Departments in a school that might wish to focus on 'Learning by building' include the design and technology department and the mathematics department, as well as the computer Club.

2.5.2 Dan—Working in an Interest-Driven Space

A critical role of the facilitator would be to create a starting point for students who may be cautious in trying out something new for the first time. Some of the students had volunteered to join the programme, and some had been selected by the teachers, but all were new to 3D modelling and it was apparent at the start that most of the students were hesitant in trying out the various tools on their own as they were afraid, to a certain extent, of making mistakes. The main hurdle for them was not picking up the basic tools, and it was figuring out how to use these tools in the world to actually knowing what to build with them.

By observing how students worked, their personalities and characters, and by talking to them about their ideas, facilitators can identify what their ideas might be and then make suggestions based on these ideas. The facilitators tried not to intervene excessively, even when the students seem to be stuck at a problem, as jumping in too early might take authorship away from the student, which may result in the learner giving up prematurely.

The facilitation is intended to spark interest in the students. For instance, there was a student, Dan, who wanted to build a water fountain based on the logo of the school. At first, he created it using a simple plane and coloured it blue, but after some deliberation, he felt that a static body of water did not look authentic. The facilitators told Dan that he could look for scripts to create movement in the water. Dan was very excited at the prospect at creating a virtual representation of the fountain and readily did research on how he could achieve that effect. His enthusiasm and excitement in trying to create the fountain led him to create many iterations of the water fountain design, and eventually he managed to manipulate his original object further by adding sounds to it using scripts, making it more realistic.

Rather than providing step-by-step instructions on how to use the tools to build objects in the environment, facilitators can give feedback and make suggestions. If the student is still unable to build the object, facilitators will step in to draw the student's attention to a particular action. These are the facilitation moves that the facilitators would take to help them become unstuck and follow through with their creative process.

The facilitators observed that when the students reached an impasse, the situation served as a good learning opportunity for them as they learnt how to work through

problems on their own. With persistence, some of them even saw how they could complexify their ideas. Take the example of Dan who first designed the water fountain as a static object. It took Dan several persistent cycles of de-bugging and iterations before he got to his final artefact, which was much more complex than his original design.

As students like Dan became more comfortable with new challenges by eagerly pursuing more complex designs, they become more engaged and spend more time on their own experimenting and investigating with confidence. With this added confidence in their own abilities, the students take ownership for their own learning and understanding. It is the personal accomplishment of breaking the impasse, plus having the final artefact that validates the students' confidence and self-esteem. Research has shown that a sense of validation is important for students and can serve as a means to help students gain a sense of belonging in the academic environment, especially those who do not perform well academically (Linares & Muñoz, 2011).

2.5.3 Adam—Being Driven by Interest and Becoming Motivated

Lepper and Cordova (1992) reported a series of studies that demonstrated how injecting fun in learning resulted in an increase in interest and learning. A vital dimension in nurturing the joy of learning is that students derive high levels of intrinsic motivation and learning efficacy when they are working in areas that they are most interested in.

To create as much possible ownership and at the same time the highest learning outcomes, it was critical for students to be included in all the stages of the design process, from conceptual to construction. The students were asked to decide, independently, which areas they would want to improve in their school. Initially, as the teachers were new to the project, they adopted a more task-oriented approach and were conservative in giving the students autonomy in building what they wanted. The students felt lost and pressured in meeting the tasks dictated by the teachers. It was only when they were able to freely express themselves that the students discovered their own capacities for creative and collective problem-solving. When given full autonomy to build objects in the virtual campus, the students started doing their own research, questioning and exploring and even learning coding on their own, without being prompted by the teachers.

For instance, a student, Adam was adamant on building a rock climbing wall in the sports complex, but found it challenging at first as he could not find an appropriate location for it. He had to figure out how the wall would look like and, more importantly, how he would integrate it into the existing infrastructure of the school, and then figure out how to build it using the OpenSim 3D modelling tools and scripting

language. Because Adam had a personal interest in rock climbing, he was intrinsically motivated to build the wall and showed persistence in solving problems that he had encountered along the way. The teachers and researchers, without overly controlling the process, encouraged Adam to solve the problems he faced in the process, supporting his self-initiation and experimentation.

Here we see that these student's accounts support the research done by Vansteenkiste (2006) and colleagues that fostering intrinsic learning goals will lead to positive effects on student motivation learning, and achievement, as opposed to promoting the goals in a controlling manner. If students feel pressured or controlled in the learning process, or if the goal conditions are inflexible and narrow, learning is less likely to be enjoyable and purposeful and their persistence at the learning activities are likely to be forestalled.

In doing so, students cultivate competencies and skills that go beyond just routine cognitive tasks, such as the ability to critically seek and synthesize information, the ability to create and innovate and the ability to self-direct one's learning (Dede, 2010).

2.5.4 Tim—Sharing and Interacting as Part of the Making Process

A part of making also embraces the ability to share not only the object that has been created, but also the process of making. The editor-in-chief of *Make* magazine, the magazine which reportedly provided the catalyst to the maker movement, writes of how sharing leads to inspiring others in a 'virtuous circle' that happens when people document and share their projects with others (Frauenfelder, 2011). The projects that he has shared online has spurred others to work on their own projects, who, in turn, share their projects, which further inspires others.

From discussions with the facilitators, it was clear that the students were motivated by a large part, through sharing. When a student had discovered a new action, or a new way of creating an object, they would excitedly tell their classmates about it, inspiring the rest of them to start tinkering with their new-found discovery. Also, because the students were all designing simultaneously in the same OpenSim environment, they were able to see other's design in real time.

For instance, when one student, Tim, created a motorcycle in the environment, he felt that it was no fun if he was the only one with it. He urged the rest of his peers to create motorcycles too so that they could all join in the fun and share his excitement. Tim got his friends interested and shared with them how he created it, and as a result, he got his peers to learn a new action.

We made two observations from this incident: the value of having fun in learning and the importance of interaction between students. The amount of enjoyment a student derives from a self-discovery can be contagious, and this enjoyment is an

intense experience in which students will devote enormous amounts of time, energy and commitment to.

The peer interactivity that was observed was a natural process that the students gravitated to gradually. The students would typically work in pairs, but started collaborating with one another through an exchange of ideas. Some students would also prefer to seek help from their peers, instead of approaching the facilitators. As the study was set in an informal learning environment, the students would walk over to each other's desks and engage one another actively and freely with feedback and ideas. There was a vibrant exchange as students started to articulate their ideas verbally by critiquing each other's work.

Critical in those interactions is in establishing a sense of shared goals, meanings and ideals. In fact, the facilitators revealed that peer critique was probably of more value than the teacher's critique because students could empathize more with each other's views and perspectives.

These observations are consistent with Vygotsky (1978), who argued that social interactions are essential for cognitive development and that the communication among peers is an effective way for individuals to attain skills and knowledge valued by a by a particular society, which in this case, the OpenSim environment.

2.5.5 Designing a Student-Centred Learning Environment

After a series of scaffolded learning activities to familiarize students with the building tools in the open-source environment, students were given opportunities to start exploring and figuring things out on their own. Some students relished working on their own more than others, and some students who were more passive would not ask for help even when they were faced with difficulties. Translating this idea required educators to know how much and when to dispense the smallest dose of instructions possible to ensure forward progress that which is purposeful without instruction.

In the words of Papert, the role of the teacher is to 'create the conditions for invention rather than provide ready-made knowledge' (Papert, 1993). Creating a learning environment that consciously breaks such a mindset is challenging, as the facilitators talk about the struggles of realizing this:

> Initially the teachers found it a struggle trying to grasp the concept of allowing the students decide what they want in the environment.....they wanted everything to be prim and proper, so it's quite weird. If they want everything prim and proper, the classroom desk to look as realistic as the real life desk, these kind of standards were imposed on the students. So the students felt like there's no motivation to do what they wanted so they struggled a lot. They felt very suffocated so to an extent that hampered their progress initially. It was only when we were able to convince the teacher to let what the students wanted that they changed. Some of the students when they were able to design what they want, after a while when they get to improve on the designs.....Also they are more confident that they are able to come up with such detailed product so they don't mind doing [what the teachers wanted]. So it's a different approach. Initially they were pressured .....They feel compelled to do it so it's different, different form of motivation.

The teachers appreciated the opportunities afforded by the approach to gain insights into the design intuitions (Lim, 2015) which their students brought to the classroom. In order to do so, they had to take a step back and allow the students to involve themselves in the conception and elaboration of their own ideas. If the teachers were apprehensive about a design that the students had created, they would ask the students to articulate their thought processes and allowed time for more iterations and meaningful discussions. This helped the students in gaining confidence in their own abilities, especially in deciding what was worth keeping or what needed to be tweaked further. The teachers' approach became less task oriented; they kept an eye out for students who were off task, but allowed for those who were on task to work independently.

It was observed that because the students were involved in all the stages of the design process from idea to construction, there was a high level of student ownership generated. When a new teacher had been assigned to head the club, she engaged the students in questions about the tools and the software, getting the students to explain the tools functioned in the virtual campus, thus subverting the normal relationship that a student and teacher would normally have. As a result, the confidence levels of the students rose and showed more initiative and self-assurance in executing their ideas and designs.

2.6 Conclusion

The Singapore education system is highly regarded internationally and has been consistently among the top-ranking countries of international evaluation studies. However, while Singapore students produce consistently high results in such tests, government leaders recognize and acknowledge the apparent lack of thinking skills and creativity among students (Tan & Gopinathan, 2000). Efforts have been made to go beyond the focus on content knowledge to one that promotes active learners with a creative and critical thinking culture within schools.

There are basically three issues that can be considered in this remaking of the context of education in Singapore, namely

(1) State craft and street craft
(2) Minds on and hands on
(3) Planning and playing.

Singapore's main narrative since the days of independence has been that she is a city–state with few to no natural resources. Hence, the latitude for failure has been kept to a minimum for fear of detrimental consequences to the state and economy. The developmental rhetoric of the past four decades has been predicated upon good planning for the foreseeable future. To date, Singapore has been quite successful by these economic criteria.

Going forward, this same philosophy of governance may not be as relevant because the rate of change is exponential. While planning is useful and needful, over-planning

without a deep embodied interaction with the ground or phenomena may well lead to plans that become obsolete before they are even executed.

Today's world and success in this ever-changing *milieu* require a disposition less for planning but more towards adapting to change and tapping on networks to both bring about change and influence change. Each national economy and education system is struggling to stay ahead of the change game. To reiterate, dispositions are not taught, rather they are cultivated in and through rich embodied experiences within social practices.

Hence, the implications for state craft and street craft need to be understood and managed carefully through ongoing conversations. By dint of her geopolitical context and her globalized economy, Singapore is particularly exposed to the vagaries of sociopolitical and economic forces external to the country; however, this does not mean that we are unable to create new contexts which can impact upon others as well.

Students and learners are the best people to ask as to what interests them and what they are passionate about; the thing is that they learn to suppress the time and effort invested in exploring these interests because the rhetoric from the state and societal groups is that these exploratory diversions are potentially a waste of time (they know it is not, but this is the rhetoric that they receive) because they represent inefficient expenses of time and resources, which could be better invested in more direct, outcome-driven behaviours. Tinkering and the playful experimentative disposition are not generally accorded with their due value in Singapore.

Thus, there is only so much that these creative spaces can be structured for (e.g. *Scape along Singapore's Orchard Road), because being given the room, the resources and the autonomy to spend significant time exploring one's (ostensibly non-curricular-relevant) interests requires a renegotiation of the implicit social contract between citizen and state.

Policy-makers need to understand that the value of these creative diversions lies not directly within the learning within the interest domain (e.g., skateboarding, knitting) but in the literacies and dispositions engendered by the socially networked embodied practice that participation in such interest domains involves. These literacies and dispositions can (and should) be mediated (through brokering) to be directed towards improved performance in more traditionally understood outcomes (e.g. academic grades).

The state-sponsored structuring should therefore manifest itself through the brokering and not in the setting aside of creative spaces per se. More can be done to harness the contributions of the specialized schools, to the wider system of education. These schools can come together in ways which enable them to be a significant influence towards play and imagination.

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