Introduction

The Singapore Ministry of Education’s (MoE) Masterplan 3 (2010) has called for a change in Singaporean schools. The MoE has recognized that direct-instruction pedagogy, with its emphasis on worksheets and memorization, while producing good test-takers, is not producing the entrepreneurial, imaginative, innovative thinkers that the government feels is important to ensure Singapore’s continued growth. Thus, MoE’s Masterplan 3 calls for a change to inquiry pedagogy, with an emphasis on the 21st century skills of self-directed learning (SDL) and collaborative learning (CoL). Of course, MoE still wants high test scores, too!

At Nan Chiau Primary School (NCPS), the administration and the teachers are taking the MP3 very seriously. With external funding support from Qualcomm’s Wireless Reach Initiative, NCPS has implemented a set of major transformations of their teaching and learning practices. As described in the following sections, five transformations were observed in 2012 in the third grade (prior to scaling up into other grade levels):

- Transformation #1—Pedagogy and Curriculum
- Transformation #2—Technology
- Transformation #3—Students Became Self-directed and Collaborative Learners
- Transformation #4—Parents’ Attitudes
- Transformation #5—Teachers’ Attitudes

Taken together, these transformations amount to a true culture change in the school.

Most excitingly, the impact on the third-grade children is by and large what was desired:

- Test scores on multiple-choice questions (MCQ) showed a slight advantage to the students in the classes where the traditional direct-instruction pedagogy was employed in comparison to the students in classes where inquiry pedagogy and smartphones were employed.
- But test scores on open-ended questions, where students needed both content and 21st century skills, showed a significant advantage to the students in classes where inquiry pedagogy and smartphones were employed.

In what follows, we first describe in more detail each of the five transformations, and then we describe the impact of these transformations on student achievement in grade 3 (referred to as “P3”—Primary 3 in Singapore) children.

Transformation #1:
Pedagogy and Curriculum

In English language instruction, the team of curriculum developers and third grade English teachers at Nan Chiau Primary School transformed the MoE-specified STELLAR (2008) curriculum that employed direct-instruction pedagogy, into the ICTmobilised.STELLAR (abbreviated as i.m.STELLAR) curriculum that employed...
a form of inquiry pedagogy, drawing on two world-recognized pedagogical strategies:

- **P4C, Philosophy for Children**, developed by the philosopher Matthew Lipman (1980) with the goal of helping children learn how to ask “philosophical questions”—deep questions, that went to the heart, the assumptions, of the issues under instruction. P4C draws on the Socratic method of learning pioneered initially in Plato’s dialogues. Learning how to ask a question and how to respond when asked a question—that’s what P4C has focused on.

- **Steps to Better Vocabulary Instruction**, Marzano’s (Marzano & Pickering, 2005) methods go beyond just memorizing the meanings of words; quite the opposite. Marzano’s methods help children understand words by building relationships and links among the words, by using words in their proper contexts.

These inquiry-oriented instructional techniques were a perfect match for smartphone technology:

- The children used the Internet that was literally embedded in the palms of their hands to explore questions and have verbal discussions to resolve issues. For example, when a question came up, the children would say: “Ask the phone.” Now, the children knew better than to trust everything “the phone” said, i.e., the answers returned from the Internet. The children learned to look at more than one Website, and they engaged in conversation about the results from their searches. To foreshadow a later section, we point out here that the students using the smartphones with the P4C pedagogy scored exceedingly high on the open-ended, oral, question-answering parts of their tests. Clearly, the P4C helped the children develop valuable 21st century skills.

- In **Figure 1**, we present an entire lesson where P4C and Marzano are combined into a coherent, cohesive series of learning activities. In each of the activities, children were engaging in some form of inquiry. As we describe more fully in the next section, the Nokia 710 smartphones, running Windows Phone 7, were outfitted with a suite of educational apps embedded in an app called MyDesk. For example, in the top on the right, the child went to the Web to find a picture that illustrated some element in the story he/she just read. The children used a KWL charting app within MyDesk to analyze the story they read. The children used their smartphones to join their COI—their Community of Inquiry—to have a conversation (textual) about an issue in the story.

- More specifically, the children had apps on their smartphones that enabled them to use the words in a
This is the evidence of the missing buffalo.

She don't believe that her best friend would spread bad comments about so she go and find evidence to prove it.

John's headache is a red herring to avoid questions about his test result.

The discovery of a woman's hat at the murder scene was a red herring to the detectives as the murderer was a male.

Red herring is a sort of clue that misleads you.

**Figure 2.** Using SketchBook to draw a picture to develop and demonstrate word understanding and then to write an appropriate sentence.

- variety of contexts: drawings and animations (SketchBook), concept maps (MapIt), and paragraphs (NotePad). It is our sense, based on discussions with the teachers and interviews with the children and analyses of classroom interactions (captured on video), that the use of multiple-linked representations (Goldman, 2003) played a key role in the children's developing an understanding of words.

- In fact, we observed students first creating a drawing or animation that explained the word, and then they created the sentence that described their picture. For example, in **Figure 2**, top row, middle picture, we observed the student writing the sentence after he drew the picture.

- Now, notice the image and sentence in the bottom row on the right: "Red herring is a sort of clue that misleads you." That sentence is more a definition of the word than a sentence depicting a situation in which the word was used, e.g., top row, middle picture: "The discovery of the woman's hat at the murder scene was a red herring to the detectives as the murderer was a male." The English teachers used these student-produced artifacts as a formative assessment; the child who did the picture in the bottom row, middle, clearly understood the notion of a red herring, but it is less clear that the child who did the picture in the bottom row, right side, actually understands the notion of a red herring, since he/she did not use the term to describe his/her picture.

In science, the pedagogy that was used is called Seamless Learning (SL). The idea behind SL is that learning takes place all the time and everywhere, in school as well as after school; learning is, in effect, 24/7.

- For example, in one assignment, students went home and helped their fathers learn about the digestive system. In that effort, the child and the father might create a concept map together. Each child then recorded a question-and-answer session with his/her father about what had been learned about the digestive system. And, finally, the next day in school, a child's partner listened to the recorded Q-and-A session to evaluate it for correctness.

Note that all activities described above were enabled by and done on the child's smartphone, which is, appropriately enough, called a handphone in Singapore.
At its core, Seamless Learning is a form of social constructivism, which in turn is a form of Dewey’s “learn by doing” pedagogy:

- "They [teachers] give the pupils something to do, not something to learn; and the doing is of such a nature as to demand thinking, or the intentional noting of connections; learning naturally results." (Dewey, 1916)

Note too that Marzano’s pedagogy is all about intentionally building connections among the words, about understanding how the words are related to each other. Thus, both in English and in science, while the particular flavors of pedagogy have their differences, the pedagogies are, at their roots, inquiry-oriented, learn-by-doing pedagogies that reinforce each other.

Just as in English, the mobile technology (the apps in MyDesk) afforded the students the ability to use multiple modalities—multiple media in science. Figure 3 presents two children's understandings of how the digestive system works, rendered using SketchBook in an animation that is annotated with text.

In 2012, all eight P3 science classes used an inquiry pedagogy and smartphones (about 300 students) while three of five P3 English classes used an inquiry pedagogy and smartphones. (Thus, three classes of students were exposed in both science and English to an inquiry pedagogy and smartphones.) Science had earlier piloted the inquiry curriculum with three P3 classes, and thus 2012 was a scale-up year for science. However, for English, it was a pilot year. In fact, in science, the teachers actually developed differentiated curriculum in order to expressly address the range of learners in the HA (High Achievers), MA (Medium Achievers), and LA (Low Achievers) classrooms.*

*In Singapore primary schools, tracking still takes place. Using end-of-year test scores as the main basis, students are placed into HA, MA, LA classes—Higher Achievers, Medium Achievers, and Low Achievers.

Transformation #2: Technology

In the P3 science and English classrooms, students used smartphones—Nokia 710s running Windows Phone 7 and equipped with a suite (MyDesk) of educational apps, e.g., Notebook, MapIt, SketchBook, etc., as essential tools for learning. In a meta-study (Norris, Hossain, & Soloway, 2011) of 1:1 laptop programs, we observed that only when students used computing devices as essential tools—as opposed to supplemental tools—did student achievement increase. In classrooms where computing devices are used as supplemental, we saw that the students only used their computing devices for a few tasks during the school day or week. In contrast, in those classrooms that used their computing devices as essential, the computing devices were used for a variety of tasks every day.

In moving from supplemental to essential use of computing devices, there was an increased demand for network connectivity. Both Wi-Fi and cellular were used in the school, while cellular was used primarily outside of the school. The IT support staff at Nan Chiau and SingTel, the cellular provider for Nan Chiau’s children, all felt the pressure from the increased demand of 300+ students accessing the network on a regular basis throughout the school day.

Transformation #3: Students Became Self-directed and Collaborative Learners

Teachers observed over the course of the school year (2012) that the students did develop more self-directed and collaborative learning skills. For example:

- Self-directed Learning: With Internet-connected smartphones virtually glued to the palms of their hands, students grew more independent and more inquisitive. Teachers observed them asking questions that were not exactly in the curriculum—and then pursuing answers for their questions using not only their technology, but also conversations with their peers. One student, for example, found the reflection of water on the ceiling to be thought-provoking. On the classroom portal—called the Community of Inquiry (COI)—the student posted this question: Why is the reflection of water like that? The student went on to engage in a chat with his fellow students about his question. Many such questions were posted in the classroom’s COI.

The teachers, over the course of the year, learned how to nurture this growing independence. Teachers encouraged students to see school and learning as 24/7—use the technology to link the abstract ideas explored in the classroom to the concrete, real-world instantiations that appeared on the students’ walk home, appeared at the dinner table, turned up at the shopping mall.

Examples of Collaborative Learning:

- As we mentioned in the earlier discussion of Seamless Learning, a student’s partner (the boy on
Figure 4. An example of collaborative learning—student–student.

Figure 5. An example of collaborative learning—teacher–students.

the right in Figure 4) listened to the answers given by the other student’s (the boy on the left) father, and then held a discussion about the accuracy of the father’s understanding of the digestive system and what instructional strategies could be used to better help their father learn about the digestive system.

- Not only did student–student exhibit collaborative learning, but teacher–students also were engaged in collaborative learning. For example, in Figure 5, we see a science teacher, who was an art teacher by training, in deep conversation with children in her classroom. Teachers developed questioning techniques; rather than being “wrong,” student responses were always opportunities for conversation.

Transformation #4: Parents’ Attitudes

At the beginning of 2012, the parents were nervous about the “new” program in science and English. They were concerned that their children were “playing” with the phones and not doing their homework. Mr. Tan, the principal, fielded a number of concerned calls from parents. However, over the course of the year, the concerns seemed to evaporate, as the parents saw their children producing interesting artifacts, spending considerable time on their devices doing so, and doing well on the end-of-year school tests.

A survey of the parents’ attitudes and beliefs was conducted at the end of the term. Two specific results from the survey are displayed in Figure 6a and 6b. The survey demonstrated that only a small percentage of parents did
Transformation #5: Teachers' Attitudes
At the beginning of 2012, there was concern that the inquiry pedagogy would be too difficult to implement, and it would take up additional class time to use the technology. However, over the course of the semester, those fears turned out to be groundless. In fact, one teacher said “Teaching is fun now. I know what I am supposed to teach, but I don’t know how it will go in class. I have to follow the students’ responses, so the path is different in each class.” This teacher is talking about using her skills as a teacher in a way that she hadn’t been using them when she was enacting direct-instruction pedagogy, with its emphasis on the use of worksheets and memorization. The sentiment expressed by this one teacher was widely held by others.

End-of-Year Test Scores: An Analysis
There is one more element to describe: end-of-year (2012) test scores for the students in P3 English and P3 science;

English: Since three classes of students used an inquiry-oriented, smartphone-based pedagogy, and five classes used a traditional direct-instruction, worksheet-based pedagogy, we can compare the performance of these two groups.

- **Multiple-choice questions:** While slight, on the MCQ portion of the year-end exam, there was a statistically significant difference in favor of students in the traditional instruction classes when compared with the students in the inquiry-oriented classes. Yes, worksheets are an excellent preparation for MCQ tests.

- **Open-ended questions:** On questions where students were asked to either construct a textual response or engage in an oral discussion, there was a statistically significant difference in favor of inquiry-oriented students when compared with the students in the traditional instruction classes. And that difference was the opposite of slight! Interestingly, on the open-ended questions, the children needed to access essentially the same content as was tested in the MCQ portion of the year-end test, but in the open-ended questions the students needed to truly understand the content, since they were required to put together answers that were not on any worksheet.

Thus, in contrast to the students in the traditional instruction classes that demonstrated a mastery of the content on the MCQ portion of the test, the students in the inquiry-oriented classes demonstrated not only a mastery of the content but also a mastery of important 21st century skills, such as constructing answers on the fly and engaging in thoughtful conversation.

Science: All students in P3 were in inquiry-oriented, smartphone-using classes; unlike the situation in English

where there was a control group that could be used for comparison, there was no control group in P3 science. But since the students in the science classes took a test at the end of the first half of the year (April) and then a test at the end of the year (November) we can look at growth over the year. We also compared the students’ scores in 2012 with their scores in 2011 and 2010. Here are the key findings:

The science students in P3 are definitely learning a vital 21st century skill: how to respond to open-ended questions. Here is the evidence:

- The whole cohort (HA, MA, LA) improved more on the Open-Ended (OE) questions than on the Multiple-Choice Questions (MCQ).
- The whole cohort improved significantly on the Open-Ended questions when compared with how they did on the OE questions in 2010 and 2011.

And it is key that the students are not doing better on OE at the expense of MCQ; while the students are not showing significant gains on the MCQ section, they are not showing any significant drop, either. Interestingly, as we see below, the largest gains are coming from the MA and LA groups.

It appears that the technology-supported, inquiry pedagogy-based learning experiences are significantly benefiting the MA and LA groups. The HA group already had very high scores on both sections, MCQ and OE, but the MA/LA cohorts improved more than the HA cohort on the OE section.

Lessons Learned
In what follows we identify several “take-aways” from the Nan Chiau experience:

**Lesson #1: Curriculum change can’t be placed on the backs of teachers:** We found several strategies that were key in developing and deploying effective inquiry-based curriculum that exploited the affordances of the mobile technology:

- Typically teachers are given pencil-and-paper curriculum but asked to also teach with computing devices. Administrators will say: “the teachers will figure it out.” The fact, documented repeatedly recently by The New York Times (Richtel, 2011–2012), that student achievement has not been significantly impacted, even with all the money spent on computing devices, is clear evidence that the teachers did not “figure it out.” Indeed, when left to the individual classroom teacher, the computing devices are used only as supplements to the existing paper-and-pencil curriculum. And, as we have documented, supplemental use of computing devices does not lead to increased student achievement (Norris, Hossain, & Soloway, 2011). Thus, at Nan Chiau, at the outset, we recognized the need for curriculum support if the curriculum was going to be changed substantially. Both in science and English, the school hired curriculum developers to take a
leadership role in changing the curriculum, but they worked with the teachers in a collaborative relationship. A team designed the revised curriculum, with teachers playing a supportive role, but not a time-consuming leadership role.

Neither the curriculum developers nor the teachers had experience with the MyDesk software, with smartphones, and with inquiry pedagogy at the beginning of this project. Thus, no one really understood how the affordances of the technology (hardware + software) could be best leveraged when creating learning activities for the students. Therefore, we borrowed the notion of “agile development” (Rasmussen, 2010) that is gaining currency in the Web development world and applied the “agile” notion to arrive at “agile curriculum development.” Thus, rather than develop a whole semester’s worth of curriculum at one go, we developed one lesson and tried it out. Based on how that lesson was received by the students and the teachers, we tweaked our design techniques on the next lesson. This iterative design proved to be a productive development strategy.

At Nan Chiau, by and large, the students already were scoring well on their end-of-year tests. Thus, teachers asked: “Why do you want me to change? I am already clearly doing a good job.” But, as responsible professionals, when the principal gave them a lesson embodying the new curriculum, pedagogy, and technology, the teachers enacted the lesson—even though they were uncertain as to its value. However, once the teachers saw the positive change in the students’ behaviors and performance, they were more willing to cooperate in helping to change the subsequent lessons.

Like many teachers at schools all over the world, teachers at Nan Chiau had common planning periods, where they met to discuss educational issues, e.g., once a week, the P3 science teachers met together, as did the P3 English teachers. However, the teachers felt that they needed to actually see teachers more experienced in the inquiry-oriented pedagogy actually enacting a lesson. Thus, the teachers rearranged their schedules, reducing the amount of time they met in common, in order to allow them time to visit each other’s classrooms—to see inquiry-oriented pedagogy being enacted. Conversation is good, but first-hand experience is also important. Interestingly now that other primary schools are looking to adopt the curriculum/pedagogy/technology used at Nan Chiau, these other schools are sending their teachers to observe the Nan Chiau teachers in action.

Lesson #2: The appetite for software is insatiable: While MyDesk provided five productivity tools, i.e., writing (Blurb), concept mapping (MapIt), KWL charting (KWL), voice recording (Recorder), and drawing and animating (SketchBook), the teachers and students wanted more apps, new apps, constantly! This desire for new apps caused several serious problems:

- Even for Windows Phone 7 there are a myriad number of apps available; that’s the upside for the teachers and students. But, for the downside, because of the architecture of Windows Phone 7, those myriad “external” apps were not able to be integrated smoothly into MyDesk. This lack of integration resulted in wasted time, lost work, and other such headaches for students and teachers. We are redesigning MyDesk for Windows Phone 8 and Android, which should give more architectural power to enable “external apps” to be more seamlessly integrated into MyDesk.

- The special-purpose, external apps were time-consuming to find and to learn to use. The teachers complained that, just like the problem with creating new curriculum, they don’t have the time to go out and find new apps for the students. And the teachers complained about the amount of time it took to learn a new app, since its interface was invariably idiosyncratic. Since typically the special-purpose apps were used for only one class period, it simply wasn’t worth the time to learn to use the new app. While curriculum developers can do a better job of finding apps to be included in the lessons, the learning-curve issue still remains.

Lesson #3: It takes time to change. While the research literature is filled with educational studies that take two weeks from start to finish, we have found that for an innovation to truly have an impact, serious time must be allotted to making that innovation stick. Invariably things go wrong; mistakes are made. At Nan Chiau, a small team started five years ago with a pilot science classroom and, over the years, the team has grown and grown; now essentially all the faculty are involved, hence the label: cultural change.

Concluding Remarks: The Transformation Engendered a Cultural Change

The five transformations caused changes in behaviors and beliefs at Nan Chiau. Moving from employing a direct-instruction, memorization-oriented pedagogy to an inquiry, question-asking, and conversing pedagogy is a major change in behavior and belief. And, after enacting an inquiry lesson where there was substantial group discussion and observing the impact of that discussion on the students, one teacher, who had been quite skeptical and vocal about that skepticism, commented: “The children can learn without me telling them.”

We feel that the five transformations have engendered a deeper, more lasting change in the P3 administrators, faculty, and parents—a cultural change in values (see Transformation, 2013). For example, while teaching at Nan
Chiau before the transformations was not a chore or an unpleasant activity, the comment, noted earlier, from one of the teachers that “teaching is fun now” is a clear indication of a change in behavior, belief, and values. As a professional, what this teacher—and, for the most part, what all the P3 educators involved with this effort—value is doing a good job, while deriving joy from doing a good job.

It is still early at Nan Chiau. We are scaling up—enacting the five transformations—in other grades and subjects over the next few years. We look forward to reporting on the details of that transformation process—and its impact on the culture of the school.

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